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Comparison of True FISP with Turbo SE in Ovarian Imaging

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Purpose: To compare the signal pattern of True FISP (true fast imaging with steady state precession) with that of T₂-weighted TSE (turbo spin echo) sequencing in several ovarian pathologies and to clarify the pathologies that may be misdiagnosed when True FISP is used as a fast T₂-weighted MR (magnetic resonance) imaging technique.

Methods: A total of 56 patients with 58 ovarian lesions were prospectively studied. The histopathological diagnoses were surgically confirmed in all patients. All MR images were acquired with a 1.5T MR scanner. After routine MR examination (T₂-weighted sagittal imaging with a turbo spin echo sequence and T₁ and T₂ transverse imaging with a spin echo and turbo spin echo sequence, respectively), True FISP was performed in the sagittal plane with a fat-saturation technique. The acquisition times for the True FISP and TSE techniques were 27 s and 4 min, 42 s, respectively. Three radiologists interpreted all images according to three grading scores and with particular reference to the difference in signal pattern between the two sequences (1 = similar signal patterns in the ovarian lesions in both True FISP and TSE images; 2 = partially different signal patterns in both True FISP and TSE images; and 3 = conflicting signal patterns in both True FISP and TSE images).

Results: Those assigned a score of “1” included 30 patients with 30 ovarian lesions (12 malignant lesions and 18 benign lesions); those assigned a score of “2” included 10 patients with 10 lesions (two malignant and eight benign); and those assigned a score of “3” included 16 patients with 18 ovarian lesions (two malignant and 16 benign). With the influence of the fat-suppression technique excluded, eight ovarian lesions showed conflicting signal patterns between the two sequences and high signal intensity of hemorrhaging in the corresponding lesion in T₁-weighted images. Lesions of both high and low signal intensity in TSE images appeared as lesions of high signal intensity in True FISP images. About 14% (8/56 lesions) of the True FISP and TSE signal patterns in ovarian pathology were conflicting in this study.

Conclusion: The results indicate that the True FISP technique cannot replace the T₂-weighted TSE technique in the evaluation of ovarian pathology. T₁-weighted images with or without fat suppression are required for the evaluation of ovarian lesions with FISP images.

Keywords: *magnetic resonance imaging, ovary, ovarian tumor, True FISP*

Introduction

MR (magnetic resonance) imaging is considered a problem-solving technique in the assessment of adnexal masses.^{1,2} MR imaging correctly character-

izes malignant and benign ovarian tumors in 89% of cases versus 85% by ultrasound.³ Among the various approaches to MR imaging, T₂-weighted imaging has been the most important sequence for evaluating anatomy and pathological changes in the pelvis.

True fast imaging with steady state precession (True FISP), a gradient-echo technique with fully

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refocused transverse magnetization, has often been used as a fast T_2 -weighted MR imaging technique for evaluating normal fetal brain maturation.⁴ One favorable imaging feature inherent to True FISP is a bright signal from still water; moreover, because of the shorter scan time of the sequence in comparison with T_2 -weighted turbo spin-echo (TSE) imaging, True FISP is expected to serve as a valuable clinical tool offering faster T_2 -weighted imaging for evaluation of pelvic pathology.

However, True FISP imaging has an inherent $\sqrt{T_2/T_1}$ contrast^{5,6}; therefore, its signal patterns in the sequence often differ from those in T_2 -weighted TSE imaging under several conditions.

The purpose of this study was to compare the signal pattern of True FISP with that of T_2 -weighted TSE sequencing in several ovarian pathologies and to clarify the pathologies that can be misinterpreted when True FISP is used as a fast T_2 -weighted MR imaging technique.

Materials and Methods

1) Subjects

A total of 56 women (ranging in age from 19 to 82 years, with a mean age of 48) who were either suspected of having or known to have had ovarian lesions and who were referred to our hospital for surgery between July 2002 and April 2004 were eligible for this study. The histopathological diagnoses of a total of 58 lesions were surgically and pathologically confirmed in all patients. The lesions included 16 malignant lesions (five clear cell carcinomas, five serous cystadenocarcinomas, two endometrioid adenocarcinomas, three mucinous cystadenocarcinomas, and one immature teratoma) and 42 benign lesions [14 endometrial cysts, 10 dermoid cysts, eight non-tumor cysts (follicular, simple and corpus luteum cysts), five serous cystadenomas, two mucinous cystadenomas, two fibromas, and one thecoma].

This study was approved by our institutional review board and all patients provided signed informed consent.

2) MR imaging

All MR scans were acquired with a 1.5T MR scanner (Symphony, Siemens, Erlangen, Germany) equipped with a pelvic phased-array coil. After a routine MR examination (T_2 -weighted sagittal and transverse imaging, and T_1 -weighted transverse imaging with and without chemical fat-suppression), True FISP was performed in the sagittal plane with a chemical fat saturation pulse to improve the contrast of soft tissue.⁷ The k-space filling with this technique was centric-ordered.

The imaging parameters of 2D True FISP were as follows: TR/TE, 5.3/2.6 ms; flip angle, 70 degrees; FOV, 220 × 140 mm; matrix, 256 × 163; slice thickness/gap, 5/2 mm; number of averages, 1; and acquisition time, 27 s. The imaging parameters of 2D TSE sequencing were as follows: TR/TE, 3 500/105 ms; flip angle, 180 degrees; and matrix, 512 × 208. The FOV (field of view) and slice thickness were the same as those of 2D True FISP. The acquisition time for 2D FSE (fast-spin echo) sequencing was 4 min, 42 s. Eighteen images were obtained in the sagittal plane in each sequence.

3) Data evaluation

All ovarian lesions were characterized prospectively from T_2 -weighted sagittal and transverse images, T_1 -weighted transverse images with and without chemical fat-suppression, and sagittal True FISP images. Therefore, the presence of fat or blood products was predictable before qualitative data evaluation with T_2 -weighted TSE sequencing and True FISP.

Three radiologists independently interpreted the signal patterns of the two sequencing methods of all images according to three grading scores. The signal patterns in the ovarian lesions were classified as follows: “1,” similar signal patterns in the ovarian lesions in both the True FISP and TSE images; “2,” partially different signal patterns in the ovarian lesions in the True FISP and TSE images, which could lead to misinterpretation (i.e., failure to depict nodular lesions in cystic tumors) but generally clarifies the character of the ovarian lesion; and “3,” conflicting signal patterns in the ovarian lesions in the True FISP and TSE images.

Images were evaluated at the same slice level in which the ovarian lesions were clearly depicted in both pulse sequences. Where ovarian lesions appeared with a high signal component in T_1 -weighted images, we referred to T_1 -weighted images with fat suppression to determine whether the fatty component influenced the signal contrast in T_1 -weighted images to the same extent. In instances where the readers disagreed, a consensus interpretation was sought.

Results

The signal patterns scored as “1” included 30 patients with 30 ovarian lesions (seven non-tumor cysts, four clear cell carcinomas, four serous cystadenocarcinomas, four serous cystadenomas, four endometrial cysts, two endometrioid adenocarcinomas, one immature teratoma, one mucinous cystadenocarcinoma, one mucinous cystadenoma, one fibroma, and one thecoma); those

Table 1. Signal intensity pattern of score 1 patients

Pathology	Numbers of Lesions	True FISP	T ₂ WI	T ₁ WI	T ₁ WI with fat suppression
Non-tumor cyst	7	High	High	Low	
Clear cell carcinoma	4	High	High	Low	
Serous cystadenoma	4	High	High	Low	
Serous cystadenocarcinoma	4	High	High	Low	
Endometrial cyst	4	High	High	Low	
Endometrioid adenocarcinoma	2	High	High	Low	
Immature teratoma	1	High	High	Low	
Mucinous cystadenocarcinoma	2	High	High	Low	
Mucinous cystadenoma	1	High	High	Low	
Fibroma	1	Low	Low	Low	
Thecoma	1	Low	Low	Low	

Table 2. Signal intensity pattern of score 2 patients

Pathology	Numbers of Lesions	True FISP	T ₂ WI	T ₁ WI	T ₁ WI with fat suppression
Endometrial cyst	5	High	High, but partially Low	Low, but partially High	Low, but partially High
Mucinous cystadenocarcinoma	2	High	High, but partially Iso	Low	
Mucinous cystadenoma	1	High	High	Low	
Fibroma	1	Iso	Iso, but partially Low	Low	
Non-tumor cyst	1	High	High, but partially Low	Low, but partially High	Low, but partially High

Table 3. Signal intensity pattern of score 3 patients

Pathology	Numbers of Lesions	True FISP	T ₂ WI	T ₁ WI	T ₁ WI with fat suppression
Dermoid cyst	10	Low	Iso-High	High	Low (suppressed)
Endometrial cyst	5	High	Low	High	High
Clear cell carcinoma	1	High	Low	High	High
Serous cystadenocarcinoma	1	High	Low	Iso-High	Iso-High
Serous cystadenoma	1	High	Low	High	High

scored as “2” included 10 patients with 10 lesions (five endometrial cysts, two mucinous cystadenocarcinomas, one mucinous cystadenoma, one non-tumor cyst and one fibroma). Those scored as “3” included 16 patients with 18 ovarian lesions (10 dermoid cysts, five endometrial cysts, one clear cell carcinoma, one serous cystadenocarcinoma, and one serous cystadenoma). The signal patterns in the T₁-weighted, T₂-weighted, and True FISP images of ovarian lesions assigned a score of “1” are summarized in Table 1; those assigned a score of “2” and “3” are summarized in Table 2

and Table 3, respectively. All ovarian lesions assigned a score of “3” exhibited a high T₁ signal intensity whereas those assigned scores of “1” and “2” exhibited a low T₁ signal intensity. (Two ovarian lesions assigned a score of “2” showed a partial high T₁ signal intensity.) Therefore, these results indicated that signals in T₁-weighted images strongly influenced the grading score. The reasons are provided below.

First, all ovarian lesions assigned a score of “1” exhibited a similar signal pattern in True FISP and TSE images (Fig. 1), whether a high or low T₂

Fig. 1. A 32-year-old woman with endometrioid adenocarcinoma. Both the True FISP image (a) and TSE image (b) demonstrate similar signal patterns for each component [cystic components (arrows) and solid components (short arrows)] in the tumor.

Fig. 2. An 82-year-old woman with mucinous cystadenoma. Most tumor signals (arrows) in the True FISP image (a) and TSE image (b) are high intensity and similar, but the nodules on the wall (white arrows, (b)) were not apparent in the True FISP image. It is notable that the nodules on the cystic wall in the ovarian lesion were believed to be neoplasm. These components were easily missed in the True FISP image.

signal was seen in the lesion. For ovarian lesions assigned a score of “2,” a partial difference was visible between True FISP and TSE images (Fig. 2); however, the partial differences seen in the signals in the ovarian lesions were caused by artifacts or limited intratumoral contrast in the True FISP images. Most ovarian lesions assigned a score of “2” showed similar signal patterns in the two sequences.

On the other hand, ovarian lesions assigned a score of “3” showed conflicting signal patterns (Fig. 3), whether a high or low T_2 signal was seen in the lesion.

It should be noted that lesions showing both high and low signal intensities in TSE images exhibited high signal intensity in True FISP images (Figs. 2 and 3).

The presence of hemorrhagic changes in ovarian

Fig. 3. A 37-year-old woman with endometrial cyst. The True FISP image (**a**) shows increased signal intensity in the cyst (arrows); in contrast, the TSE image (**b**) shows decreased signal intensity.

lesions (excluding lesions with fatty components) often resulted in conflicting signal patterns between the two sequences. About 14% (8/56 lesions) of the signal patterns of ovarian pathology showed conflicts between the True FISP and TSE images once the influence of the signal of fatty components was excluded from this study.

Discussion

Obtaining T_2 -weighted images with a TSE sequence that have sufficient image quality to allow for evaluation of pelvic abnormality often requires at least five minutes. Faster imaging of the pelvis may reduce the number of artifacts caused by intestinal peristalsis and respiratory motion. The need clearly exists for faster T_2 -weighted imaging, and several shorter T_2 -weighted images have previously been compared with TSE images. However, these sequences—such as single-shot FSE with half-Fourier acquisition and multi-shot echoplanar imaging—could not replace TSE sequencing because of their limited spatial resolution and low tissue contrast.⁸⁻¹⁰

True FISP provides a higher signal-to-noise (S/N) ratio for the assessment of uterine anatomy definition, as reported previously.⁷ Therefore, it is natural that True FISP can be expected to function as an innovative and faster T_2 -weighted imaging method for evaluating ovarian pathology. To be sure, the sequence may provide a higher spatial resolution and S/N ratio than other faster T_2 -weighted imaging sequences. However, as our results show, conflicting signal patterns are visible

in the True FISP and TSE images of ovarian lesions; moreover, small components such as nodular lesions on the cystic wall can be easily missed in True FISP images. Because they can contribute to misinterpretations, these pitfalls can have serious consequences.

The former pitfall, the disparity in signal intensity between the two sequences, may be due to the inherent T_1 contrast of True FISP imaging. Our study results indicated that the presence of a high T_1 signal intensity in the lesions was the cause of the disparity. In the hemorrhagic ovarian lesions, both T_1 and T_2 shortening may occur and the $\sqrt{T_2/T_1}$ ratio is unpredictable. However, with fat-suppressed T_1 -weighted images, T_1 -shortening such as hemorrhagic pathology may be easily diagnosed. Therefore, considering that the influence of T_1 shortening affects the signal in True FISP images, the sequence will be useful as a faster MR imaging technique for ovarian pathology. In other words, T_1 -weighted images (with or without fat-suppression) play an important role in the evaluation of ovarian lesions by using True FISP images.

In this paper, we emphasize that True FISP imaging should not simply be recognized as a faster T_2 -weighted imaging technique. Because it is important that hemorrhagic ovarian lesions often show low signal intensity in TSE images and the low signal intensity of ovarian lesions were limited to some pathology in general. It leads to a specific diagnosis or allows narrowing of the differential diagnosis.¹¹

The latter pitfall, easily missing small components or low tissue contrast in True FISP images, is

also important because these imaging features may present valuable clues to the presence of a malignancy.¹¹

For these reasons, as well as its unpredictability and complex signal patterns, True FISP should not be used as a faster T₂-weighted imaging technique for evaluating ovarian pathology.

The main limitations of our study are the small number of subjects and the heterogeneous pathology. Future investigations are needed to establish the clinical usefulness of the True FISP sequence for characterizing ovarian tumors.

In this study, no case exhibited low signal intensity in True FISP images and high intensity in TSE images of ovarian pathology. Considering the principle of the True FISP signal, such signal patterns are believed to be almost impossible. Therefore, our results appear not to contradict the theory.

Another limitation is that the signal patterns we obtained with True FISP were based on a sequence with centric ordered k-space filling. A sequence with linear ordered k-space filling can be expected to show a different signal pattern in ovarian pathology. This difference is important to further investigation and interpretation.

Conclusion

Our results indicate that the True FISP sequence cannot replace T₂-weighted TSE as a T₂-weighted imaging sequence in the evaluation of ovarian pathology, despite its advantage of a short acquisition time, because the signal pattern of ovarian pathology in True FISP images is less specific than, and sometimes contrary to, that in TSE images. It must be understood that True FISP sometimes provides different contrast from TSE sequencing.

In the assessment of the influence of T₁ contrast, T₁-weighted images with or without fat-suppression are necessary in the evaluation of ovarian lesions by using True FISP images. It should be emphasized that a high-intensity T₁ signal often results in a disparity in signal intensity between True FISP and TSE images.

Further investigation is needed to establish the clinical usefulness of the sequence.

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