Acta Radiologica, 2016

MR appearance of normal uterine endometrium considering menstrual cycle: differentiation with benign and malignant endometrial lesions

Authors' names

Fuki Shitano[1], Aki Kido[1], Masako Kataoka[1], Koji Fujimoto[1], Kayo Kiguchi[1], Yasutaka Fushimi[1], Ikuo Konishi[2], and Kaori Togashi[1]

Affiliation

1 Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University, 54 Kawahara-cho Shogoin, Sakyo-ku, Kyoto, 606-8507, Japan

2 Department of Gynecology and Obstetrics, Kyoto University Graduate School of Medicine, 54 Kawahara-cho Shogoin, Sakyo-ku, Kyoto, 606-8507, Japan

Corresponding author's name, address, fax and e-mail

Aki Kido

Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University, 54 Kawahara-cho Shogoin, Sakyo-ku, Kyoto, 606-8507, Japan

Tel:+81-75-751-3760

Fax:+81-75-771-9709

e-mail: akikido@kuhp.kyoto-u.ac.jp

Abstract

Background: The thickness and signal intensity (SI) of normal uterine endometrium on T2-weighted images (WI) changes depend on the menstrual cycle phase. Cases of normal endometrium that appear similar to endometrial lesions sometimes occur, and may result in misdiagnosis.

Purpose: To investigate normal endometrial appearance in luteal phase (LP) compared to that in follicular phase (FP), and to differentiate these appearances with those of endometrial lesions.

Material and Methods: Thirty-two normal volunteers prospectively underwent MR examinations during LP and FP. Patients with pathologically confirmed endometrial polyps (n=9), hyperplasia (n=7) and cancer (n=15), who underwent MR examinations, were evaluated for comparison. Endometrial appearance was categorized into the following five types on sagittal T2-WI and compared between LP, FP and endometrial lesions: type 1) homogeneous higher SI, type 2) homogeneous iso SI, type 3) a bright midline and a peripheral iso SI layer, type 4) a lower/iso SI central line, type 5) heterogeneous lower/iso SI. Endometrial thickness and SI were measured and also compared.

Results: Endometrial lesions were more frequently categorized as type 5 than normal endometrium ($p<0.05$). Endometrial thickness in LP (mean: 1.0cm) was significantly greater than that in FP (0.6cm), but not significantly different from polyps (1.1cm), hyperplasia (1.0cm) and cancer (0.9cm). SI in FP was significantly higher than that in LP and that of all endometrial lesions.

Conclusion: Differentiation between normal endometrium in LP and endometrial lesions may be difficult based on thickness alone. Heterogeneous low SI may help to differentiate normal endometrium from endometrial lesions. Performing MRI during FP may also help due to higher SI of normal endometrium.

Keywords: uterine endometrium; luteal phase; MRI; endometrial lesions

Introduction

The initial imaging modality of choice for evaluating abnormal uterine endometrium or abnormal uterine bleeding is generally ultrasonography. Magnetic resonance imaging (MRI) may be a useful problem-solving tool when ultrasonography findings are inconclusive (1-3). Thickened endometrium on MRI is indicative of endometrial lesions (4-8); however, normal endometrial thickness can increase to a mean peak of over 1.0 cm in the luteal phase (9, 10). Signal intensity (SI) on T2-weighted images (WI) is also known to change from the early proliferative to the mid-secretory phase (11). This can result in imaging findings of "thickened endometrium with decreased SI" on T2-WI, which is in fact normal variation but mimics other endometrial lesions and may lead to over-diagnosis. For accurate MRI diagnosis of endometrial abnormalities, it is important to known the range of variation in "normal endometrial appearance". However, there are a limited number of studies investigating normal variation of the endometrium and its differentiation from endometrial lesions.

The aim of this study was to evaluate the appearance of normal endometrium in the luteal phase (LP) and follicular phase (FP), as well as the appearance of endometrium with lesions including endometrial cancer, endometrial polyps and endometrial hyperplasia, and to compare the endometrial thickness and SI of the endometrium with and without endometrial lesions on T2-WI.

Material and Methods

Study population

The protocol of this study was approved by the Ethics Committee of our institute. The study population consisted of two groups: prospectively recruited healthy volunteers and patients with confirmed endometrial lesions who were retrospectively selected.

For the group of healthy volunteers, the inclusion criteria were as follows: healthy females having regular menstrual cycles. A regular menstrual cycle was defined as a range of 24-35 days (12). A total of 38 females with regular menstrual cycles (mean age: 30.8 years, age range: 20-44 years) were recruited from May 2012 to January 2014 and written informed consent was obtained from all subjects. The exclusion criteria were as follows: taking exogenous hormones, having endometrial lesions or distortion of uterine cavity on MRI, and having inadequate MR image quality for evaluation. Distorted endometrium was excluded as the thickness of the endometrium could not be measured accurately or the area of the endometrium was not large enough for evaluation of the appearance and SI. From the 38 subjects, six were excluded for the following reasons: taking an emergency contraceptive pill (n=1), accompanying endometrial lesion (n=1), endometrial distortion on MRI (n=3) (submucosal uterine leiomyoma (n=1), multiple leiomyoma (n=1), large adenomyosis in the anterior uterine wall (n=1)), and poor image quality due to severe bowel motion artifacts (n=1). As a result, 32 subjects were included in the study.

Data from patients with endometrial lesions was extracted from the computer databases of the Departments of Pathology, Gynecology and Radiology between August 2008 and December 2013. The inclusion criteria were patients who were pathologically confirmed to have endometrial lesions and patients who underwent MR examinations on 3.0-T magnet units before surgical procedures. Patients with the following three endometrial lesions were included in this study: 15 patients with endometrial cancer which was limited within the endometrium (mean age: 53.2 years, age range: 41-66 years) (5 pre-menopausal and 10 post-menopausal patients), seven patients with endometrial hyperplasia (mean age: 38.0 years, age range: 22-51 years), and nine patients with endometrial polyps (mean age: 47.0 years, age range: 29-70 years). Endometrial

hyperplasia was confirmed with dilation and curettage in four patients and with hysterectomy in three patients. The exact phases of patients' menstrual cycles on MR examination could not be determined retrospectively, as sequential menstrual cycle was not written in the patients' charts and abnormal bleeding made it difficult to distinguish from menstruation.

MR scanning protocols

MR examinations for the 38 healthy female subjects were performed during LP (Cycle Day (CD) 14-34, 1-12 days before the next cycle (late LP in 27/32 women, early LP in 5/32 women)) and FP (CD 6-16, 12-30 days before the next cycle) of the next or after the next cycle. The number of days between the two examinations was 12-46 days. Among the 32 subjects, 28 underwent MR examinations at sequential menstrual cycles. The other four subjects underwent the second MR examinations two menstrual cycles later. All subjects were asked to note the beginning of the subsequent menstrual cycle to allow menstrual cycle phase confirmation. MR examinations were obtained using a 3-T MR unit (Toshiba Medical Systems, Otawara, Japan) with a phased-array coil. Sagittal T2-weighted fast spin-echo (FSE) images, axial T2-weighted fast-advanced spin echo (FASE) images and sagittal T1-weighted FSE images were obtained. Sagittal T1 and T2-WI were obtained in mid-plane of the uterus. Acquisition parameters for each sequence are summarized in Table 1. Pre-medication, including anti-cholinergic drugs, were not administered.

MR examinations for the 31 patients with endometrial lesions were performed using 3.0-T magnet units (MAGNETOM Trio and Skyra, Siemens, Erlangen, Germany) with phased-array coils. Sagittal T1-weighted spin-echo (SE) images and sagittal and axial T2-weighted FSE images were obtained. Acquisition parameters for each sequence are summarized in Table 1. Anti-cholinergic drugs (Buscopan; Nippon Boehringer Ingelheim, Tokyo, Japan) were administered in 14 of 15 patients with endometrial cancer, in all 7 patients with endometrial hyperplasia, and in 7 of 9 patients with endometrial polyps.

Image analysis

The MR images of the 32 healthy subjects and 31 patients were independently interpreted for the appearance of the endometrium, including endometrial lesions, by two radiologists with six years (F.S. reader A) and 17 years (A.K. reader B) of experience in female pelvic MRI, respectively. The readers were blinded to the pathological findings but were aware that there were patients in the group of healthy subjects because of the different image protocols between the healthy subjects and patients. The readers visually evaluated the normal endometrium of the healthy subjects in LP and FP, and the endometrium of the patients with lesions, on sagittal T2-WI to categorize as the following five types: type 1) homogeneous higher SI than endocervical mucosa, type 2) homogeneous iso SI to endocervical mucosa, type 3) two layer appearance with a bright midline and a peripheral iso SI layer compared to endocervical mucosa, type 4) the presence of a lower/iso SI central line within the endometrium compared to endocervical mucosa, type 5) heterogeneous lower/iso SI areas within the endometrium compared to endocervical mucosa (Fig. 1).

For all subjects, the maximum thickness of the endometrium was measured on sagittal T2-WI by one radiologist. As for the measurement of SI in the endometrium, polygonal regions of interest (ROIs) were drawn to delineate the contour of the endometrium at the mid-sagittal plane of the uterus. Reference ROIs were drawn on the paraspinal muscles and subcutaneous fat in the hip, avoiding vessels and ghosting artifacts. Since MR units and acquisition parameters were different between the volunteers and the patients, the SI of each ROI was converted to the relative SI (rSI) by the following formula according to a previous report (13):

rSI = (mean SI of each uterine region - mean SI of paraspinal muscle) / (mean SI of fat - mean SI of paraspinal muscle) x 100

Statistical analysis

The difference in the five types of endometrial appearance between normal endometrium in LP and FP was examined in each of the five types using Fisher's exact test (MedCalc Software, version 12.7.2.0, Ostend, Belgium). Each endometrial lesion was also compared with normal endometrium in LP and FP in each of the five types using Fisher's exact test.

The maximum thickness and rSI of the normal endometrium was compared between LP and FP by paired Student's t-tests (MedCalc Software, version 12.7.2.0).

The maximum thickness and the rSI of the normal endometrium in LP and FP were compared with each of the three types of endometrial lesions by unpaired Student's t-tests.

The maximum thickness of endometrium with endometrial cancer were compared between pre and post-menopausal patients by an unpaired Student's t-test.

A P value of less than 0.05 was regarded as statistically significant.

Concordance of the two readers' results of the appearance of the endometrium was measured by the kappa coefficient. A kappa value less than 0.00 signified poor agreement; 0.00-0.20, slight agreement; 0.21-0.40, fair agreement; 0.41-0.60; moderate agreement; 0.61-0.80, substantial agreement; 0.81-1.00, almost perfect agreement (14).

Results

The results of the evaluation of the appearance of the endometrium are shown in Table 2. Type 1 was identified more frequently in the normal endometrium in FP than that in LP and endometrial lesions by both readers. A significant difference was observed between normal endometrium in FP and LP ($p<0.05$) by both readers, and between normal endometrium in FP and endometrial cancer ($p<0.05$) by reader B. More than half of the cases of endometrial cancer were categorized as type 2 by both readers, but a significant difference between endometrial cancer and normal endometrium in LP was only observed ($p<0.05$) by reader B. Another significant difference was observed between normal endometrium in FP and endometrial polyps ($p<0.05$). Type 3 was observed more frequently in the normal endometrium in LP by both readers. A significant difference was observed between normal endometrium in LP and endometrial cancer ($p<0.05$) and between normal endometrium in LP and FP ($p<0.05$) by reader A. Type 4 was more frequently identified in the normal endometrium in LP, and a significant difference was observed between normal endometrium in LP and endometrial cancer ($p<0.05$) by both readers. Type 5 was observed significantly more in each of the endometrium with endometrial lesions than in normal endometrium ($p<0.05$) by both readers.

Interobserver agreement was substantial or almost perfect for the evaluation of the endometrial appearance in FP and LP and endometrial hyperplasia, polyps, and cancer ($\kappa = 0.67$, 0.68, 0.78, 0.81 and 0.89, respectively).

The maximum thickness of the normal endometrium in LP and FP compared with that of each endometrial lesion is shown in Fig. 2. The mean maximum thickness of the normal endometrium was 1.04 cm (range: 0.39-2.04 cm) in LP and 0.65 cm (range: 0.21-1.40 cm) in FP, and the difference was significant ($P<0.05$) (Table 3). There was no significant difference in the maximum thickness between the normal endometrium in LP and that of all endometrial lesions including endometrial cancer, hyperplasia and polyps ($p = 0.14$, 0.74 and 0.88, respectively). When compared to the normal endometrium in FP, a significant difference was observed with endometrial hyperplasia and with endometrial polyps ($p<0.05$), but not with endometrial cancer ($p = 0.07$). With respect to endometrial

cancer, there was no significant difference in the maximum endometrial thickness between pre and post-menopausal women ($p = 0.90$) (mean: 0.83 mm, range: 0.31-1.48 cm, mean: 0.87mm, range: 0.10-1.70 cm, respectively).

The rSI of the normal endometrium in LP and FP compared with that of each endometrial lesion is shown in Fig. 3. The rSI of the normal endometrium was significantly lower in LP than in FP ($P<0.05$). The rSI of the normal endometrium in LP was significantly higher than that of patients with endometrial cancer ($P<0.05$) and endometrial polyps ($P<0.05$), but not with endometrial hyperplasia ($p = 0.09$). Forty-eight percent of the range of the rSI of the normal endometrium in LP and 55 percent of the range of the rSI of endometrial cancer overlapped. The rSI of the normal endometrium in FP was significantly higher than that of all patients with endometrial lesions ($P<0.05$). Representative sample cases are shown in Fig. 4.

Discussion

This study demonstrated that there is a considerable overlap in the endometrial thickness and SI between normal subjects and patients with endometrial lesions.

From the results of this study, differentiation of normal endometrium, both in LP and FP, from endometrial cancer by thickness alone was difficult regardless of menopausal state. The mean maximum thickness of endometrial cancer was 0.86cm. The mean maximum thickness of the normal endometrium was 0.64cm in FP and 1.04cm in the LP, which is in agreement with previous reports (9-11, 15). However, there was a significant difference in the mean thickness of the two phases. In addition, the range of the endometrial thickness was 0.21-1.40 cm in FP and 0.39-2.04 cm in LP, despite the fact that the upper limit of the normal endometrium at reproductive age is believed to be 1cm (11, 16). These results suggest that the distinction between normal endometrium and endometrial lesions only by the endometrial thickness may be difficult depending on the menstrual cycle. Differentiation between normal and abnormal endometrial thickness might be easier if MRI is not performed during LP. Thus, scheduling recommendations might suggest MR examination prior to ovulation.

With respect to the SI of the endometrium, a significant difference was observed between all but normal endometrium in LP and endometrial hyperplasia, although considerable overlap was observed between the SI of normal endometrium and those of the endometrium with lesions as shown in Fig. 3. Difficulties due to normal low endometrial SI might also be reduced by performing MRI before ovulation. This recommendation might be important in premenopausal woman, as the incidence or prevalence of endometrial hyperplasia and polyps increases with age over age 30 (17, 18). In addition to SI, our study also suggested the use of endometrial appearance as an additional differential point. It is well known that endometrial cancer typically shows medium to low SI relative to the normal endometrium on T2-WI (5, 16, 19-23). According to our results, heterogeneous low SI endometrium (type 5) was more frequently observed in each of endometrial lesions than in normal endometrium. Heterogeneity of the endometrium can also be a differential point. In the case of endometrial polyps, the presence of a central fibrous core and intratumoral cysts are

known to be key imaging findings (4, 24), and may also be a cause of the heterogeneity of the endometrium. The SI and its inhomogeneous appearance may be useful to differentiate endometrial cancer from normal endometrium, since endometrial cancer is most frequently diagnosed at perimenopausal/ postmenopausal age, but up to 10% to 15% of cancers can occur in premenopausal patients (25, 26).

In the normal endometrium, a significant difference was observed in the SI between the two phases. Homogeneous high SI endometrium on T2-WI could be observed in FP, but only in less than 10% of subjects in LP. A pattern of iso/low SI area, such as peripheral or central iso/low SI, was observed in most of the endometrium in LP. The reason for the appearance of this pattern could not be determined as there was no correlation with the pathology observed in this study. One possible cause may be the peridecidualization of the endometrial stroma, which can be observed after cycle day 22-23 (27). In the present study, most of the MR images in LP (27/32 women) were obtained in late LP, which corresponds to the period of peridecidualization. Pathological correlation with MRI will be required for the next steps.

Classification of the appearance of the endometrium has not been previously reported. Advancements in MR units may contribute to improve detailed contrast within the endometrium. Here, we used 3.0-T MR units, resulting in higher signal to noise ratio (SNR) than the 1.5-T, 0.35-T or 0.15-T MR units previously reported for evaluation of endometrial visualization in MRI (9, 15, 19, 20, 28, 29). According to increased SNR, the slice thickness can be made thinner with increased matrix, and thus improved spatial resolution can be obtained on 3.0-T MR units. Therefore, this demonstrated that detailed structure of the endometrium could be distinguished using 3.0-T MR units. Likewise, our T2-WI were obtained with FSE, while T2-WI in previous studies were obtained with SE (9, 15, 19, 20, 28, 29). Since image acquisition time of a FSE sequence is shorter than that of a SE sequence, the images may be less affected by motion artifacts such as bowel peristalsis and breathing motion.

There are some limitations to the present study. First, the population with endometrial lesions was small. Although the patients were collected retrospectively, the study could be improved if patients were collected prospectively. Second, we determined the menstrual cycle phases at MR examination based on their menstrual cycle. A more

accurate method for determining the exact phase would be to perform hormonal or temperature measurements. Third, we could not correlate the imaging of the normal endometrium with its pathological state. It may be possible to pathologically examine patients with normal endometrium undergoing operation for other diseases, such as ovarian tumors.

In conclusion, distinction between normal endometrium in LP and endometrial lesions may be difficult using only endometrial thickness. Heterogeneous low SI may help to differentiate the normal endometrium from those with lesions. Performing MRI during FP may also help due to higher SI of normal endometrium.

Acknowledgement

The authors would like to thank Tomohisa Okada, MD, PhD (Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University), Shinya Fujii, MD, PhD (Division of Radiology, Department of Pathophysiological and Therapeutic Science, Faculty of Medicine, Tottori University), Sayaka Daido, MD (Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University) and Yuki Himoto, MD (Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University) for their contributions to this study and, Kyoko Takakura, RT (Department of Diagnostic Imaging and Nuclear Medicine, Graduate School of Medicine, Kyoto University), Yuki Kanazawa, RT, PhD (Institute of Health Biosciences, The University of Tokushima Graduate School), Hajime Sagawa, RT (Clinical Radiology Service, Kyoto University Hospital) and Naotaka Sakashita (Toshiba Medical Systems Corporation) for their technical assistance.

Declaration of Conflicting Interests

One of the authors, K. T. was provided a sponsored research program, “Researches for improvement of MR visualization (No. 150100700014)” by Toshiba Medical Systems Corporation, Japan. For the remaining authors none were declared.

Funding

This research was supported by a sponsored research program, “Researches for improvement of MR visualization” provided to one of the authors, K. T. by Toshiba Medical Systems Corporation, Japan (No. 150100700014).

References

1. Bennett GL, Andreotti RF, Lee SI, et al. ACR appropriateness criteria(®) on abnormal vaginal bleeding. J Am Coll Radiol 2011;8:460-468.

2. Vargas HA, Akin O, Zheng J, et al. The value of MR imaging when the site of uterine cancer origin is uncertain. Radiology 2011;258:785-792.

3. American College of Obstetricians and Gynecologists. ACOG Committee Opinion No. 426: The role of transvaginal ultrasonography in the evaluation of postmenopausal bleeding. Obstet Gynecol 2009;113:462-464.

4. Hase S, Mitsumori A, Inai R, et al. Endometrial polyps: MR imaging features. Acta Med Okayama 2012;66:475-485.

5. Chaudhry S, Reinhold C, Guermazi A, et al. Benign and malignant diseases of the endometrium. Top Magn Reson Imaging 2003;14:339-357.

6. Nalaboff KM, Pellerito JS, Ben-Levi E. Imaging the endometrium: disease and normal variants. Radiographics 2001;21:1409-1424.

7. Atri M, Reinhold C. Neoplasm, Benign; Endometrial Polyps; Endometrial Hyperplasia. In: Hricak H, ed. Diagnostic Imaging: Gynecology. Salt Lake City: Amirsys, 2007:128-139.

8. Akin O, Reinhold C, Rafat Z, et al. Neoplasm, Malignant; Endometrial Cancer, Characterization; Endometrial Cancer, Early Stage. In: Hricak H, ed. Diagnostic Imaging: Gynecology. Salt Lake City: Amirsys, 2007:140-149.

9. McCarthy S, Tauber C, Gore J. Female pelvic anatomy: MR assessment of variations during the menstrual cycle and with use of oral contraceptives. Radiology 1986;160:119-123.

10. Janus CL, Wiczyk HP, Laufer N. Magnetic resonance imaging of the menstrual cycle. Magn Reson Imaging 1988;6:669-674.

11. Demas BE, Hricak H, Jaffe RB. Uterine MR imaging: effects of hormonal stimulation. Radiology 1986;159:123-126.

12. Speroff L, Glass RH, Kase NG. Part 1: Reproductive Physiology Chapter 6: Regulation of the Menstrual Cycle, In: Mitchell C, ed. Clinical Gynecologic Endocrinology and Infertility Sixth Edition. Philadelphia: Lippincott Williams & Wilkins,

1999: 201-246.
13. Fujimoto K, Nakai A, Okada T, et al. Effect of hyoscine butylbromide (HBB) on the uterine corpus: quantitative assessment with T2-weighted (T2W) MRI in healthy volunteers. J Magn Reson Imaging 2010;32:441-445.
14. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-174.
15. Haynor DR, Mack LA, Soules MR, et al. Changing appearance of the normal uterus during the menstrual cycle: MR studies. Radiology 1986;161:459-462.
16. Hricak H, Stern JL, Fisher MR, et al. Endometrial carcinoma staging by MR imaging. Radiology 1987;162:297-305.
17. Reed SD, Newton KM, Clinton WL, et al. Incidence of endometrial hyperplasia. Am J Obstet Gynecol 2009; 200:678 e671-676
18. Van Bogaert LJ. Clinicopathologic findings in endometrial polyps. Obstet Gynecol 1988; 71:771-773
19. Worthington JL, Balfe DM, Lee JK, et al. Uterine neoplasms: MR imaging. Radiology 1986;159:725-730.
20. Lee JK, Gersell DJ, Balfe DM, et al. The uterus: in vitro MR-anatomic correlation of normal and abnormal specimens. Radiology 1985; 157:175-179.
21. Posniak HV, Olson MC, Dudiak CM, et al. MR imaging of uterine carcinoma: correlation with clinical and pathologic findings. Radiographics 1990;10:15-27.
22. Sala E, Wakely S, Senior E, et al. MRI of malignant neoplasms of the uterine corpus and cervix. Am J Roentgenol 2007;188:1577-1587.
23. Beddy P, O'Neill AC, Yamamoto AK, et al. FIGO staging system for endometrial cancer: added benefits of MR imaging. Radiographics 2012;32:241-254.
24. Grasel RP, Outwater EK, Siegelman ES, et al. Endometrial polyps: MR imaging features and distinction from endometrial carcinoma. Radiology 2000;214:47-52.
25. Howlader N, Noone AM, Krapcho M, et al. SEER Cancer Statistics Review, Bethesda: National Cancer Institute, 1975-2012. http://seer.cancer.gov/csr/1975_2012/ (based on November 2014 SEER data submission, posted to the SEER web site, April 2015)
26. Renaud MC, Le T, Bentley J, et al. Epidemiology and investigations for suspected

endometrial cancer. J Obstet Gynaecol Can 2013; 35:380-383.
27. Mutter GL, Ferenczy A. Chapter 9 Anatomy and Histology of the Uterine Corpus. In: Kurman RJ, ed. Blaustein's Pathology of the Female Genital Tract Fifth Edition. New York: Springer, 2002:383-419.
28. Hricak H, Alpers C, Crooks LE, et al. Magnetic resonance imaging of the female pelvis: initial experience. Am J Roentgenol 1983;141:1119-1128.
29. McCarthy S, Scott G, Majumdar S, et al. Uterine junctional zone: MR study of water content and relaxation properties. Radiology 1989;171:241-243.

Table 1: Acquisition parameters for MR imaging examinations for normal volunteers and patients.

Abbreviation: FSE = fast spin-echo, WI = weighted image, FASE = fast-advanced spin echo, TR = repetition time,

	normal volunteers			patients		
	sagittal FSE T2-WI	sagittal FSE T1-WI	axial FASE T2-WI	sagittal FSE T2-WI	sagittal SE T1-WI	axial FSE T2-WI
TR/TE (msec)	5756/80	571/12	15000/80	4000-4500/81-83	600-608/11	4500/81-83
FOV (mm)	260 x 260	260 x 260	300 x 330	260 x209-212	260 x 204-208	320 x 320
slice thickness (mm)	4	4	5	4	4	4
matrix	512 x 256	320 x 256	256 x 352	448 x 288-328	384 x 230-240	512 x 512
FA (deg)	90	90	90	90	80	90
refocusing FA (deg)	170	180	160	150	180	150

TE= echo time, FOV = field of view, FA = flip angle.

Table 2: Categorization of the appearance of the normal endometrium in periovulatory and luteal phase and the endometrium with lesions as evaluated by two readers.

Reader A	type 1	type 2	type 3	type 4	type 5	total
normal endometrium (FP)	6 (19%)	15 (47%)	4 (13%)	7 (22%)	0 (0%)	32 (100%)
normal endometrium (LP)	0 (0%)	8 (25%)	14 (44%)	9 (28%)	1 (3%)	32 (100%)
endometrial hyperplasia	0 (0%)	3 (43%)	1 (14%)	0 (0%)	3 (43%)	7 (100%)
endometrial polyp	1 (11%)	0 (0%)	1 (11%)	1 (11%)	6 (67%)	9 (100%)
endometrial cancer	1 (7%)	8 (53%)	1 (7%)	0 (0%)	5 (33%)	15 (100%)

Reader B	type 1	type 2	type 3	type 4	type 5	total
normal endometrium (FP)	10 (31%)	8 (25%)	6 (19%)	8 (25%)	0 (0%)	32 (100%)
normal endometrium (LP)	2 (6%)	3 (9%)	13 (41%)	12 (38%)	2 (6%)	32 (100%)
endometrial hyperplasia	0 (0%)	2 (29%)	2 (29%)	0 (0%)	3 (43%)	7 (100%)
endometrial polyp	1 (11%)	0 (0%)	2 (22%)	1 (11%)	5 (56%)	9 (100%)
endometrial cancer	0 (0%)	8 (53%)	2 (13%)	0 (0%)	5 (33%)	15 (100%)

*p<0.05. Abbreviation: FP = follicular phase, LP = luteal phase.

Table 3: The maximum thickness and relative signal intensities (rSI) of the normal endometrium and endometrial lesions.

	maximum thickness (cm)	rSI (%)
normal endometrium (FP)	0.64 (0.21-1.40)	83.1 (56.1-112.8)
normal endometrium (LP)	1.04 (0.39-2.04)	75.9 (56.4-109.4)
endometrial hyperplasia	0.99 (0.35-1.89)	64.8 (43.1-88.9)
endometrial polyp	1.06 (0.50-1.95)	63.2 (43.6-86.2)
endometrial cancer	0.86 (0.10-1.70)	57.2 (36.0-81.7)

Abbreviation: FP = follicular phase, LP = luteal phase.

Figure Legends

Fig. 1: The sagittal FSE T2-weighted images of the normal endometrium in luteal and periovulatory phase and those with endometrial lesions were categorized as the following five types: type 1) homogeneous higher signal intensity than that of endocervical mucosa, type 2) homogeneous iso signal intensity to that of endocervical mucosa, type 3) two layer appearance with a bright midline and a peripheral iso SI layer compared to endocervical mucosa, type 4) the presence of a lower/iso signal intensity central line within the endometrium compared to the signal of endocervical mucosa, type 5) heteorogeneous lower/iso signal intensity areas within the endometrium compared to the signal of endocervical mucosa.

Fig. 2: Maximum thickness of the normal endometrium in luteal and follicular phase and of those with each endometrial lesion. *$p<0.05$. The endometrial thickness in LP was significantly greater than that in FP. There was no significant difference between the normal endometrium in LP and that of all endometrial lesions including endometrial cancer, hyperplasia and polyps. There was a significant difference between the normal endometrium in FP and endometrial hyperplasia and between the normal endometrium in FP and endometrial polyps. There was no significant difference between the normal endometrium in FP and endometrial cancer.
FP = follicular phase, LP = luteal phase.

Fig. 3: Relative signal intensity (rSI) of the normal endometrium in luteal and follicular phase and of those with each endometrial lesion. *$p<0.05$. The rSI of the normal endometrium was significantly lower in LP than in FP. The rSI of the normal endometrium in LP was significantly higher than that of patients with endometrial cancer and endometrial polyps, but not with endometrial hyperplasia. The rSI of the normal endometrium in FP was significantly higher than that of all patients with endometrial lesions.
FP = follicular phase, LP = luteal phase.

Fig. 4 (a) – (e): Representative sagittal T2-weighted images: (a) 33-year-old woman with normal endometrium in luteal phase, (b) The same woman as Fig. 4 (a) in follicular phase, obtained 17 days later, (c) 41-year-old woman with endometrial hyperplasia, (d) 41-year-old woman with endometrial polyp, and (e) 41-year-old woman with endometrial cancer. Fig. 4 (a) was classified as type 3, and Fig. 4 (b) was classified as type 4. Fig. 4 (c), (d) and (e) were classified as type 5. In Fig. 4 (d), a prominent low signal intensity spot in T2-WI called the fibrous core of endometrial polyp can be recognized within the endometrium. In endometrial cancer (Fig. 4 (e)), the endometrial thickness was similar to that in Fig. 4 (a), but the appearance was heterogeneous.

Fig. 1

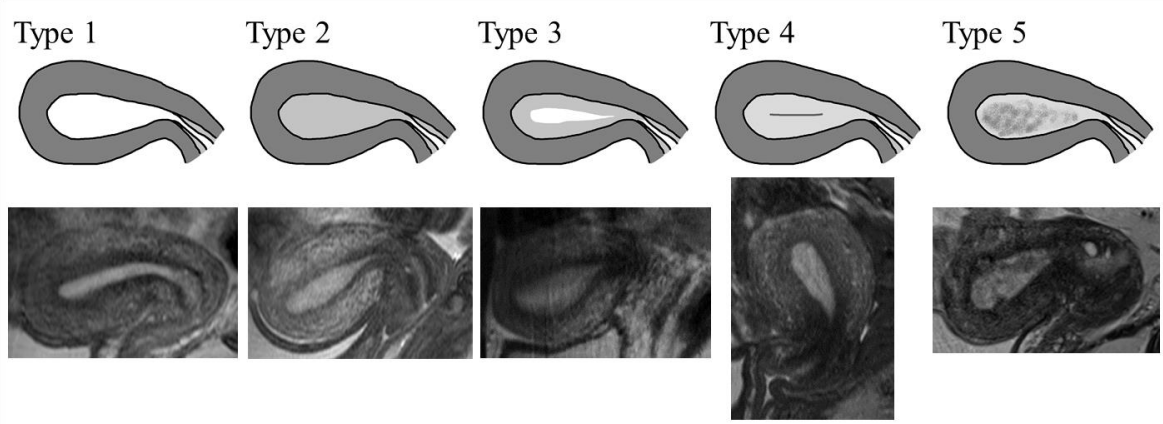
Type 1
Type 2
Type 3
Type 4
Type 5

Fig. 2

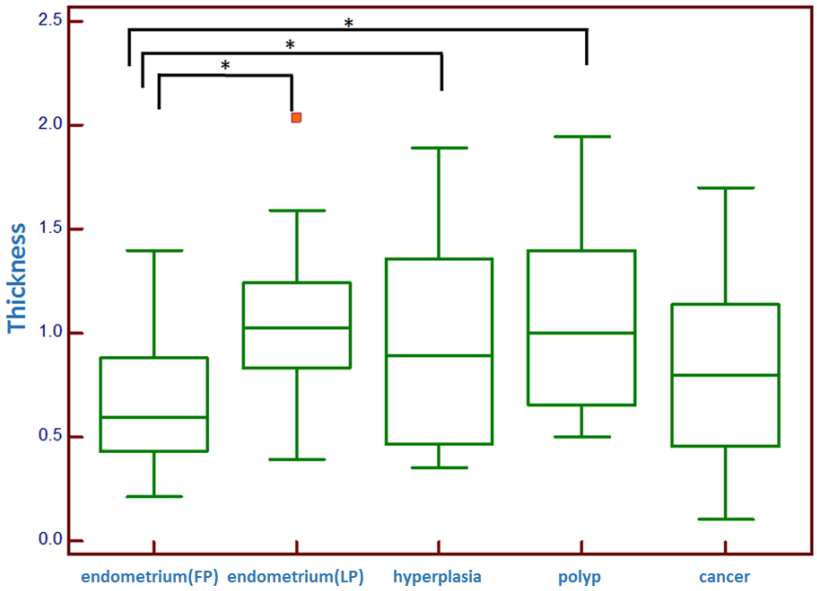
Thickness
2.5
2.0
1.5
1.0
0.5
0.0
*
*
*
endometrium(FP)
endometrium(LP)
hyperplasia
polyp
cancer

Fig. 3

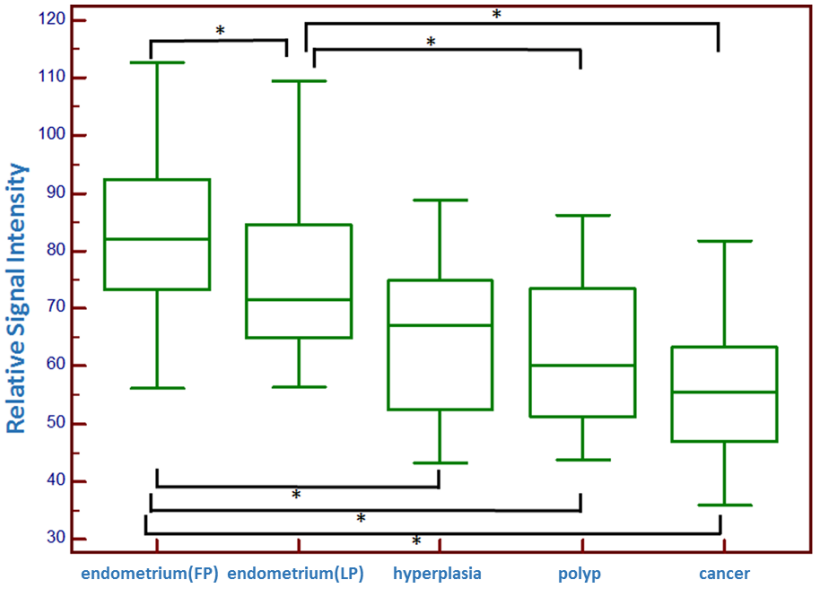
Relative Signal Intensity
120
110
100
90
80
70
60
50
40
30
*
*
*
*
*
*
endometrium(FP)
endometrium(LP)
hyperplasia
polyp
cancer

Fig. 4 (a)-(e)