A comparison of uterine peristalsis in women with normal uteri and uterine leiomyoma by cine magnetic resonance imaging

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Abstract

Objective: The non-pregnant uterus shows wave-like activity (uterine peristalsis). This pilot study was intended to determine: (1) whether uterine peristalsis during the menstrual cycle is detectable by cine magnetic resonance imaging (MRI); (2) the effects of leiomyoma on uterine peristalsis.
Study design: Mid-sagittal MRI was performed sequentially with T2-weighted single-shot fast spin-echo (SSFSE) in 3 normal ovulatory volunteers and 19 premenopausal women with uterine leiomyoma. Direction and frequency of movement of the junctional zone were evaluated using a cine mode display.
Results: Junctional zone movement was identified in all subjects. Direction of uterine peristalsis in normal volunteers was fundus-to-cervix during menstruation, cervix-to-fundus during the periovulatory phase, and isthmical during the mid- and late-luteal phases. Abnormal peristaltic patterns were detected in three of five patients with uterine leiomyoma during menstruation and in the mid-luteal phase of the cycle, respectively.
Conclusion: Cine MRI is a novel method for evaluation of uterine peristalsis. Results of this pilot study suggest that abnormal uterine peristalsis during menstruation and the mid-luteal phase might be one of the causes of hypermenorrhea and infertility associated with uterine leiomyoma.

Keywords: MRI; Uterine leiomyoma; Uterine peristalsis

1. Introduction

Studies have shown that the non-pregnant uterus is not a quiescent organ. Instead, it shows wave-like activity (uterine peristalsis) throughout the menstrual cycle [1,2]. Intrauterine pressure transducers first detected this uterine activity [3–6]. Presently, ultrasound allows the non-invasive study of the direction of uterine peristalsis. Using ultrasound, investigators can visualize endometrial wave-like activity resulting from sequential segmental contractions in the subendometrial myometrium [2].

Ultrasonographic recording has shown that peristaltic patterns in the non-pregnant uterus play a role in the reproductive process [7–9]. During the early follicular phase, peristalsis from the fundus to the cervix serves to cleanse the uterine cavity. In the late follicular and periovulatory phases, peristalsis from the cervix to the fundus dominates. It increases in intensity towards ovulation; also, it is assumed to promote sperm transport. In addition, during the mid- and late-luteal phase, the uterus shows a relative quiescence, which facilitates embryo implantation [10]. Moreover, dysfunction of this peristaltic pattern in patients with endometriosis might engender reproduction difficulties [11].

Accordingly, it has been considered that using vaginal sonography is the easiest and most convenient method for

observing uterine peristaltic activity. Notwithstanding, recent advances in magnetic resonance imaging (MRI) technique and ultrafast MRI allow us to obtain T2-weighted images of the uterus within a few seconds [12,13]. The present pilot study was intended to determine the suitability of this technique for detecting uterine peristalsis during the normal menstrual cycle by evaluating junctional zone movement on a cine mode display (cine MRI). Because very few reports specifically address uterine peristaltic activity in patients with uterine leiomyoma, the present study was also designed to determine effects of uterine leiomyoma on uterine peristalsis in otherwise healthy adult females.

2. Materials and methods

This study was performed under the guidelines of the institutional review board. Informed consent was obtained from each volunteer and patient prior to the study.

The first part of the study was designed to record the direction and frequency of uterine peristalsis during the menstrual cycle using cine MRI. These studies were conducted in three normal, healthy volunteers, aged 28–36 years (mean, 32). The mean length of the menstrual cycle in these subjects was 30.3 days. Subjects recorded their basal body temperatures (BBT) daily to confirm that they were ovulatory and to determine the date for imaging accurately. Cine MRIs were obtained during the menstrual period (days 1–3 of the cycle), follicular phase (days 7–10 of the cycle), periovulatory phase (determined by daily monitoring of luteinizing hormone [LH]), early luteal phase (days 2–3 of the high phase of BBT), mid-luteal phase (days 5–7 of the high phase of BBT), and late luteal phase (days 11–13 of the high phase of BBT).

Cine MRI was also conducted in 19 premenopausal patients aged 24–42 years (mean, 34.8 years) who had normal menstrual cycles and who had been referred for confirmed uterine leiomyoma after conventional MRI. Patients also recorded their BBT daily to define the phases of the menstrual cycle. MRI was performed during menstruation in five patients, follicular phase in two patients, periovulatory phase in one patient, early luteal phase in four patients, mid-luteal phase in five patients, and late luteal phase in two patients. The final diagnoses on the basis of findings at transvaginal sonography and conventional MRI were intramural ($n = 15$), subserosal ($n = 2$), and submucosal ($n = 2$) leiomyoma.

MRI was performed using a 1.5 T magnet, phased-array multicoil system (Horizon LX EchoSpeed; GE Medical Systems, Milwaukee, WI). T2-weighted single-shot fast spin-echo (SSFSE; effective echo time = 95 ms) images were obtained sequentially through the mid-sagittal plane of the uterus. One SSFSE image was obtained each 1.6 s during shallow respiration. A series of scans comprised 32 SSFSE images with an 6-s interval; they were acquired during 3–4 min. Imaging parameters were: repetition time (TR)/echo time (TE) = 6000/94 ms, echo train length of 85, section thickness of 7–10 mm, intersection gap of 1–2 mm, receiver bandwidth of 62.5 kHz, matrix of 256 × 256, field of view of 35 cm × 21–24.5 cm, and one-half signal acquired. All SSFSE images in one study were summated into one image on a Workstation (Advantage Windows, Version 3.1; GE Medical Systems) and displayed sequentially on the cine mode display at 250-ms intervals. Three gynecologists interpreted the images independently. Evaluated points included: (1) perception of movement of the junctional zone on the cine mode display; (2) direction and frequency of that movement, if perceivable.

The peristaltic activity of the uterus in different phases of the cycle was characterized by variable composition with respect to four types of contractions [1,14]: fundus-to-cervix contractions (peristalsis from fundus-to-cervix), cervix-to-fundus contractions (peristalsis from cervix to fundus), opposing contractions (coexisting fundus-to-cervix and cervix-to-fundus contractions), and isthmical contractions (weak peristalsis only from the uterine isthmus to the lower mid-corporal region).

Because of the small number of subjects, this entire study is defined as a pilot study. No calculations or statistical analyses were performed using these results.

3. Results

Movements of the junctional zone were identified on the cine mode display in all women (Fig. 1). The results analysed by the three interpreters were prominently concordant, especially with regard to peristaltic direction. Peristaltic frequencies were quite similar for each reader; the differences were, at most, 0.6 min^{-1}.

Table 1 and Fig. 2 present a summary of the results of studies conducted with three ovulatory volunteers. During menstruation, peristaltic waves from the fundus to the cervix with low frequency (mean frequency of three subjects, 1.0 contraction/min) were identified in all three women. In the follicular phase, uterine peristaltic activity exhibited fundus-to-cervix and cervix-to-fundus contraction waves (1.3 min^{-1}). During the periovulatory phase, cervix-to-fundus contraction waves were noted in the three women at maximum frequency (2.4 min^{-1}). In the early luteal phase, uterine peristaltic activity exhibited cervix-to-fundus and isthmical contraction waves (1.1 min^{-1}). Isthmical contractions (1.4 and 1.3 min^{-1}), but no corporal contractions, were noted in the three women during the mid- and late luteal phases.

In the second part of our study, to investigate the effects of leiomyoma on uterine peristalsis, the peristaltic activity of the patients with leiomyoma were compared with that of normal volunteers (as control). Table 2 summarizes the results of 19 patients with uterine leiomyoma. The peristaltic patterns in women with leiomyoma during the follicular phase ($n = 2$), the periovulatory phase ($n = 1$), the early

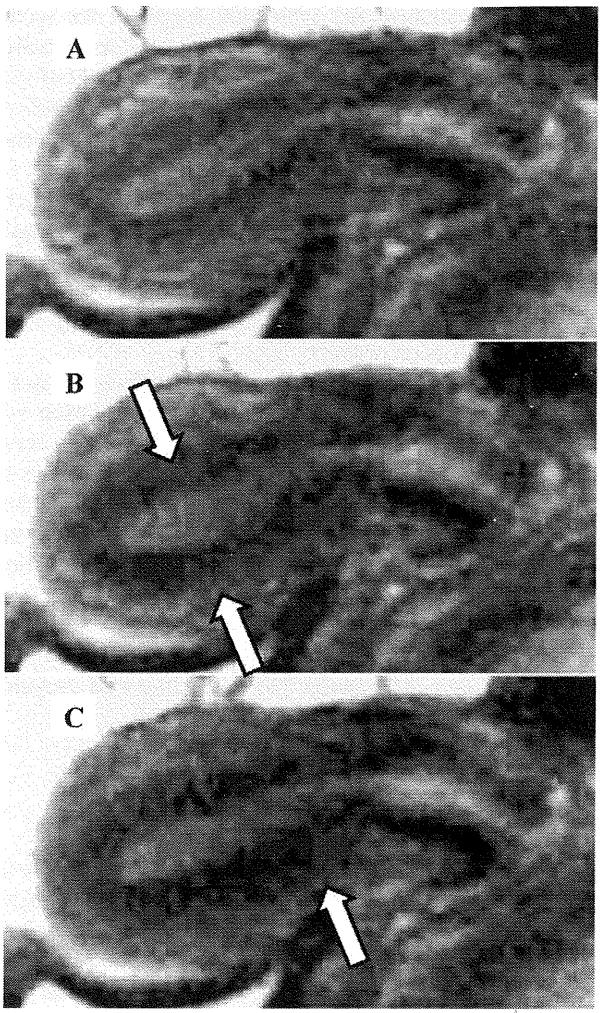

Fig. 1. Serial single-shot fast spin-echo (SSFSE) T2-weighted images show subtle changes in the appearance of the junctional zone. (A) The entire junctional zone is thin compared with that observed in B and C. (B) The junctional zone exhibits focal thickening in the upper portion of the corpus (arrows). (C) The thickest portion of the junctional zone moved close to the cervix (arrow).

luteal phase ($n = 4$), and the late luteal phase ($n = 2$) were almost identical to those of healthy women. In contrast, during menstruation ($n = 5$), the direction of uterine peristalsis was fundus-to-cervix contractions in two women with intramural myoma, isthmical contractions in two

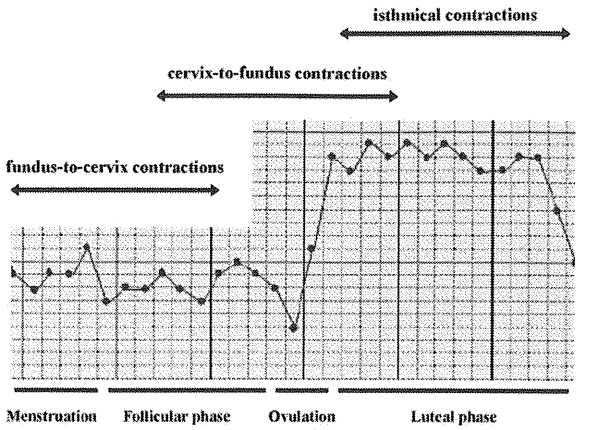

Fig. 2. Summary of uterine peristalsis during the menstrual cycle in healthy women examined by cine MRI.

women with intramural myoma, and opposing contractions in one woman with intramural myoma. In the mid-luteal phase ($n = 5$), the direction of peristalsis was isthmical contractions in two women with intramural myoma, cervix-to-fundus contractions in one woman with intramural myoma, fundus-to-cervix contractions in one woman with submucosal myoma, and opposing contractions in one woman with submucosal myoma.

Therefore, abnormal peristaltic patterns were detected in three of five patients with uterine leiomyoma during menstruation and in the mid-luteal phase of the cycle, respectively.

4. Comment

Ultrafast MRI technique allows visualization using a cine mode display. Thereby, we viewed both uterine peristalsis as a movement of the junctional zone and directional changes of contractions during the menstrual cycle. Nakai et al. reported that cine MRI can detect uterine peristalsis in only half of the cases [15]. However, their total scanning time was only half as long as that in the present study. Furthermore, they did not evaluate opposing and isthmical contractions. It should be cautioned that MRI is inferior to ultrasound in terms of time resolution because even ultrafast MRI requires intervals between scans [13].

Table 1
Direction and average frequency of uterine peristalsis during normal menstrual cycle in healthy women examined by cine MRI

Cycle phase	Subject		
	1	2	3
During menstruation	Fundus-to-cervix (1.0 min^{-1})	Fundus-to-cervix (1.0 min^{-1})	Fundus-to-cervix (1.0 min^{-1})
Follicular phase	Cervix-to-fundus (1.0 min^{-1})	Fundus-to-cervix (1.3 min^{-1})	Opposing (1.7 min^{-1})
Periovulatory phase	Cervix-to-fundus (2.7 min^{-1})	Cervix-to-fundus (2.7 min^{-1})	Cervix-to-fundus (1.7 min^{-1})
Early luteal phase	Cervix-to-fundus (1.0 min^{-1})	Isthmical (1.0 min^{-1})	Cervix-to-fundus (1.3 min^{-1})
Mid-luteal phase	Isthmical (1.0 min^{-1})	Isthmical (1.0 min^{-1})	Isthmical (2.3 min^{-1})
Late luteal phase	Isthmical (1.0 min^{-1})	Isthmical (1.0 min^{-1})	Isthmical (2.0 min^{-1})

Table 2
Direction and average frequency of uterine peristalsis in women with uterine leiomyoma examined by cine MRI

Cycle phase	Position of leiomyoma	Direction and average frequency	Number of leiomyoma	Maximum size (cm)	Hyper-menorrhea
Menstruation	Intramural	Fundus-to-cervix (0.7 min^{-1})	3	4.0	+
	Intramural	Fundus-to-cervix (1.3 min^{-1})	2	3.0	–
	Intramural	Isthmical[a] (1.3 min^{-1})	3	4.0	+
	Intramural	Isthmical[a] (1.3 min^{-1})	6	3.5	+
	Intramural	Opposing[a] (1.3 min^{-1})	6	6.0	+
Follicular	Subserosal	Fundus-to-cervix (1.3 min^{-1})	1	4.5	–
	Intramural	Cervix-to-fundus (1.7 min^{-1})	4	4.2	–
Periovulatory	Intramural	Cervix-to-fundus (1.7 min^{-1})	1	7.5	–
Early luteal	Intramural	Cervix-to-fundus (2.0 min^{-1})	4	1.0	–
	Intramural	Isthmical (2.3 min^{-1})	1	6.0	–
	Intramural	Isthmical (1.7 min^{-1})	7	6.0	+
	Subserosal	Isthmical (1.7 min^{-1})	1	6.0	–
Mid-luteal	Intramural	Isthmical (1.7 min^{-1})	4	1.0	–
	Intramural	Isthmical (2.0 min^{-1})	1	3.0	–
	Intramural	Cervix-to-fundus[a] (1.3 min^{-1})	4	4.5	+
	Submucosal	Fundus-to-cervix[a] (2.3 min^{-1})	1	2.8	+
	Submucosal	Opposing[a] (2.0 min^{-1})	1	3.6	–
Late luteal	Intramural	Isthmical (1.0 min^{-1})	2	0.8	–
	Intramural	Isthmical (1.3 min^{-1})	1	3.0	–

[a] Abnormal uterine peristaltic patterns which were detected in women with uterine leiomyoma.

Moreover, it remains unclear whether peristaltic movements of the junctional zone in our study truly represent endometrial wave-like peristalsis on ultrasound. Nevertheless, Lesny et al. have cautioned that, when an examiner tries to obtain a perfect image of the endometrial wave on ultrasound and presses too hard with a transvaginal transducer, even strong contractions during the periovulatory phase may become disrupted and random; alternatively, more complicated wave patterns may not be visualized [16]. Results of this pilot study are identical to those of transvaginal videosonography [1,2], suggesting that cine MRI is suitable for detection of uterine peristalsis without pressure on the uterus.

The causal relationship between uterine leiomyoma and infertility or recurrent miscarriage remains controversial [17,18]. Moreover, since this is a pilot study, conclusions of dysfunctional peristaltic activity in women with leiomyoma should be interpreted with caution, especially in terms of a causal role regarding fertility. Nevertheless, previous reports have suggested that the detection of disturbances of peristaltic pattern may identify new causal aspect(s) of infertility [1,11]. In the present study, abnormal uterine peristaltic patterns were detected in women with uterine leiomyoma during menstruation and in the mid-luteal phase (peri-implantation period), respectively. Abnormal peristalsis during menstruation may cause prolonged menstruation and hypermenorrhea. Corporal contractions during the mid-luteal phase may affect embryo implantation and increase the risk of miscarriage. In this regard, Eldar-Geva et al. and Healy reported that pregnancy and implantation rates in women undergoing in vitro fertilization were significantly lower in patients with intramural and submucosal leiomyoma, even when there was no deformation of the uterine cavity [19,20]. In addition, continuous fundus-to-cervix contractions were noted in women with submucosal myoma, even in the mid-luteal phase; the contractions seemed to facilitate expulsion of foreign materials from uterine cavity. These contractions might also be causally involved in the mechanisms of myoma delivery.

Although a recent report indicates using cine MRI that uterine peristalsis was focally interrupted in 4 out of 16 patients with submucosal myoma and suggests that the loss of peristalsis might have interfered with sperm transport and contributed to infertility in women with leiomyoma, the stage of menstrual cycle was not identified [21]. Since uterine peristalsis is closely cycle-related, it is possible that the apparently low number of patients (25%) exhibiting abnormal uterine peristalsis could have been due to the heterogeneous nature of the patient population examined. In the present study in which the menstrual cycle of the patient population was controlled and analysed by cine MRI as in previous study, we have demonstrated that three of five patients examined exhibited abnormal corporal contractions during menstruation and the mid-luteal phase, respectively, cautioning the need to define menstrual status in these investigations.

The results presented above are clearly preliminary. Further studies should be performed to clarify the influence of the number, size and location of the leiomyoma on uterine peristalsis. Nevertheless, we infer that cine MRI may facilitate evaluation of uterine peristaltic activity. Further investigations of uterine peristalsis in women with leiomyoma may elucidate the relationship between leiomyoma and infertility, and thereby improve determination of indications for myomectomy.

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