ORIGINAL ARTICLE

Myoma Uteri: Stiffness from MR Elastography in Thai Patients: A Pilot Study

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Objective: To study the feasibility of magnetic resonance elastography (MRE) for the evaluation of myoma uteri in Thai patients.

Materials and Methods: A prospective descriptive study was conducted between September 2020 and October 2021. Twenty-six myoma uteri patients were performed in a 3.0-Tesla MRI scanner, added with a pneumatic system generating mechanical waves. For the MRE assessment, the number of acquired slices, mean stiffness with standard deviation (SD), minimum, and maximum stiffnesses (kPa) were recorded.

Results: The mean stiffness of the myoma uteri was 3.02 kPa (range 1.83 to 5.06, SD 0.79). Their volume ranged from 56.24 to 716.35 cm^3 (mean 237.74, SD 187.63. The proportion of lesions ranged from 31.87% to 74.36% of the whole uterus (mean 44.94, SD 16.98).

Conclusion: Uterine MRE is a feasible diagnostic tool for studying the tissue stiffness of the myoma uteri, which is higher than normal uterine tissue. The mean stiffness of Thai patient myoma uteri was lower than other ethnicities.

Keywords: Myoma uteri; Uterine fibroid; Uterine leiomyoma; MRE; Tissue stiffness

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Myoma uteri, described as uterine leiomyoma or fibroid, is the most common benign tumor of female genital organs[1,2]. They are monoclonal tumors arising from the smooth muscle cells and fibroblasts of the myometrium. Their incidence varies among races from 50% to 90%[3,4]. Despite high incidence, only one-fourth show clinical symptoms, such as menorrhagia, severe dysmenorrhea, pelvic pain, and frequent urination. This disease nowadays is a main cause of hysterectomy[5].

Gynecologists usually request ultrasonography, computed tomography (CT) scan, or magnetic resonance imaging (MRI) for their clinical myoma-diagnosed patients. These examinations help confirmation of diagnosis, evaluation of disease progression, staging before a surgical procedure, and follow-up after the operation. Depending on only specific characteristic findings from the radiological examination, radiologists can conclude myoma uteri confidently more than 90%[6].

Magnetic resonance elastography (MRE) is an MRI-based method for quantitatively imaging the mechanical properties of tissues, such as liver fibrosis that increases the stiffness of the hepatic parenchyma[7]. The benefit of MRE has been studied in several organs including the liver, breast, brain, and muscle. Myoma uteri may also benefit from MRE as well[8,9].

Previous studies showed the mean stiffness of normal uteri in Chinese volunteers was 2.58±0.52 kPa[10] and the mean stiffness of uterine fibroids in U.S. patients was 4.81±2.12 kPa[11]. As mentioned before, the incidence of myoma uteri varies among races, so, the mean stiffness of myoma uteri in Thai patients may also differ from other countries.

The purpose of the present study was the feasibility of MRE use for the evaluation of myoma uteri in Thai patients.

Materials and Methods

Ethical consideration

The present study was a single-arm prospective descriptive study between September 2020 and

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October 2021. The authors' institution Ethics Committee for Human Research approved the study protocol (48/2562, HE621425). All patients signed the informed consent. The present study adhered to CONSORT guidelines.

Patient selection

Patients of at least 18 years old who were diagnosed clinically as myoma uteri, and requested for MRI of the uterus or pelvic cavity were considered for inclusion in the present study. Patients with pregnancy or emergency medical conditions such as the acute abdomen or sepsis were excluded.

Hardware and data acquisition

All examinations were performed in a 3.0-Tesla MRI scanner (Achieva dStream, software version 5.6.1.0, Philips Healthcare) using a phased-array surface coil. To perform MRE and generate mechanical waves, a pneumatic system that incorporated an active driver, placed outside the scan room, for producing continuous acoustic wave motion was used. A passive driver was placed against the body surface superficial to the symphysis pubis to induce shear waves traversing the uterus (Figure 1). An air-filled plastic tube was used for transmitting the pneumatic excitations from the active to the passive driver. A small soft pad was also placed beneath the passive driver to decrease patient vibrating sensations. The patient was placed in the supine position. The passive driver and the pelvis were wrapped together by a kidney belt to ensure direct contact of the driver with the body surface. Finally, an anterior surface coil was set up before performing an MRI examination. A repetition frequency of the drivers at 60 Hz was used for the MRE study.

To image the shear waves and measure the propagation of the mechanical waves inside the tissue from the MRE, a 2D Phase Contrast Fast Field Echo (FFE) with motion-encoding gradients and a 15-second breath-hold per slice was applied. Depending upon the myoma uteri size, two to five axial slices through the whole uterus were generally obtained to generate MRE images. Before imaging the shear wave, axial T2-weighted images were acquired to position the myoma and to be used as an anatomical reference. Each wave image slice was acquired at eight evenly spaced time points. The MRE examination was repeated once without repositioning the patient or the actuators to assess reproducibility.

Figure 1. A passive driver was placed against the body surface superficial to the symphysis pubis to induce shear waves traversing the uterus.

Data postprocessing

Post-processing of the images using MREView software version 5.6.1.0, Philips Healthcare displayed wave images, FFE or Modulus images, and stiffness images. The regions of interest (ROIs) for the whole uterus were drawn manually on axial FFE/Modulus images by an MRI technologist to measure tissue stiffness. Each pixel on an MRE image was processed by the software and converted into stiffness values. All pixels in the ROI were calculated to achieve overall stiffness values. The stiffness measurements in units of kilopascals (kPa) were displayed as average stiffness, median stiffness, minimum and maximum stiffnesses, and standard deviation (SD). The stiffness images were displayed in color where red color represented high stiffness and a dark purple color represented no stiffness.

Imaging interpretation

The axial thin-slice T2-weighted images through the whole uterus were used to determine the components of myoma uteri. The dimensions and volume of each uterus were measured and recorded in centimeters (cm) and milliliters (ml).

For the MRE assessment, the number of acquired slices, mean stiffness with SD, minimum, and maximum stiffnesses (kPa) were recorded. The stiffness maps and T2-weighted images were simultaneously interpreted to evaluate the components of myoma uteri in the area of increased stiffness which was defined by red or orange colors in the stiffness maps.

Statistical analysis

The sample size was calculated in accordance with the formula for estimating population mean. A

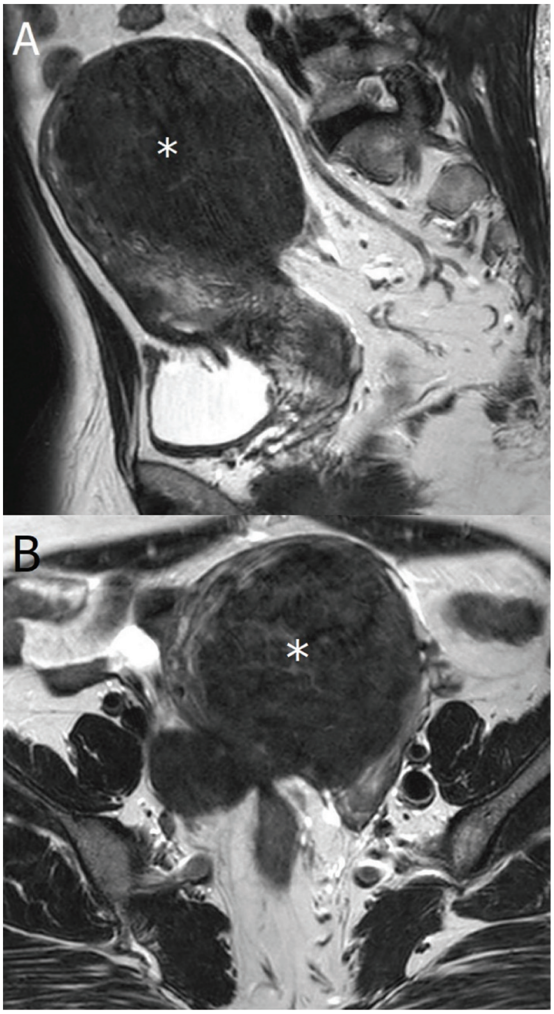

Figure 2. MRI showed a large intramural to subserous part of myoma uteri (*) at the fundus; the myoma was the hypointense signal intensity on T2-weighted images. (A) Sagittal view, (B) Axial view.

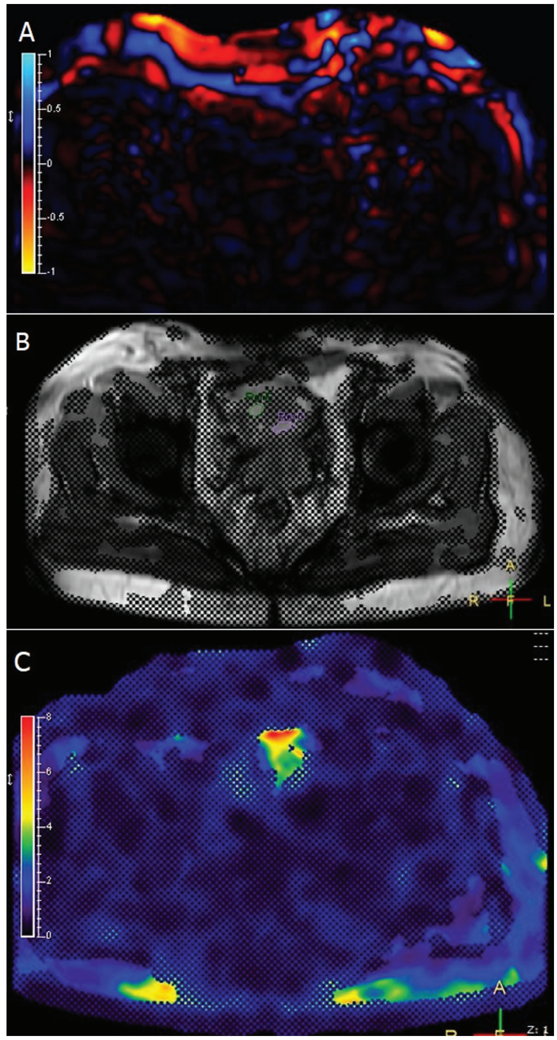

Figure 3. Demonstrating MRE images in one same slice. (A) Wave image, (B) Fast Field Echo (FFE) image, (C) Stiffness image.

sample size of 15 participants was estimated with 95% confidence interval (CI)[10,11]. To guarantee adequate population coverage, 30 participants were sought. Because of the COVID-19 pandemic situation, only 26 participants were enrolled in the study, which was still sufficient.

Continuous data were demonstrated by their range, mean, and standard deviation (SD). Statistical analyses were performed using MS Excel 2016 (Microsoft®, USA).

Results

The mean age of 26 patients was 49 years (range of 26 to 70 years old). All myoma uteri showed the hypointense signal intensity on T2-weighted MRI (Figure 2) without calcification. Post-processing software displayed wave image, FFE image, and stiffness image (Figure 3). The ROI were drawn manually to measure tissue stiffness, each pixel on an MRE image was converted into stiffness values (Figure 4).

The mean stiffness of the myoma uteri was 3.02 kPa (range 1.83 to 5.06, SD 0.79). The number of lesions distributed as single lesions (10 cases), as two lesions (6 cases), as three lesions (6 cases), as four lesions (2 cases), and as five lesions (2 cases). Their volumes ranged from 56.24 to 716.35 cm^3 (mean 237.74, SD 187.63). If the patient had multiple lesions, the lesion volume was the summation of all lesions. The proportion of lesions ranged from

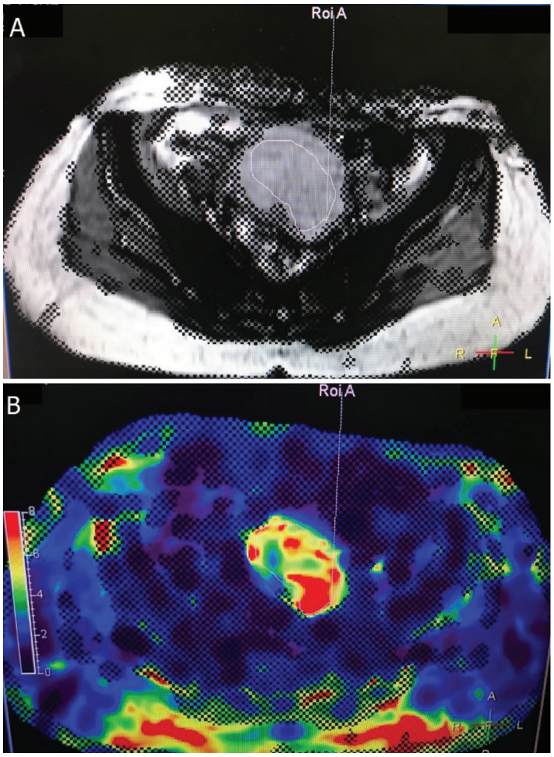

Figure 4. Demonstrating the measurement method and documented results in post-processing software. (A) The ROI was drawn manually covering the entire uterus on the axial image. (B) ROI was also shown on the stiffness image.

31.87% to 74.36% of the whole uterus (mean 44.94, SD 16.98).

The duration of the MRE was five minutes longer than the conventional MRI examinations and an additional 10 to 15 minutes were required to construct all MRE images. No adverse events occurred during the examination.

Discussion

MRI has an advantage over a CT scan in the examination of structures within the pelvic cavity, especially concerning the relationship between the uterus and the surrounding tissues. The main disadvantage of MRI, however, is the long duration of the examination around 40 to 50 minutes, compared to 15 to 20 minutes for a CT scan. Therefore, the CT scan may be preferred for a small-sized tumor or mass with a low risk of malignancy[12,13].

MRE is a recently developed technique for measuring tissue stiffness, so it provides mechanical properties within myoma uteri more than the standard T2-weighted MRI[14]. Although hysterectomy is still a first-line treatment of advanced myoma uteri, the procedure itself may result in unwanted consequences. MR-guided focused ultrasound surgery (MRgFUS) was recently introduced as an alternative non-invasive treatment to ablate tumors and reduce fibroid volumes[15]. MRE may evaluate the effectiveness of the treatment via the sequential changes of tumor stiffness[11,15]. Other treatments such as pharmacologic therapies, myomectomy, or uterine artery embolization, also increased the interest in how myoma uteri mechanical properties could differentially affect treatment responsiveness, and thus having a way to assess this variable might prove useful in predicting the response to minimally invasive myoma therapies[5,16].

The authors aimed to study the feasibility of MRE and whether it could be optimized for clinical use as part of the Thai patient's routine clinical imaging of myoma uteri. Although myoma stiffness could also be obtained by transvaginal ultrasound elastography (TVUE), the procedure itself might cause uneasiness to the patients. MRE, however, took only five minutes more than the standard MRI. The MRE should be more comfortable than TVUE[10].

The stiffness value of myoma uteri depends on the concentration of the fibrotic tissue. The mean stiffness in the present study was 3.02 kPa, which was harder than normal uterine tissue of 2.58 kPa[10] due to more fibrotic components. This value was less than the mean stiffness from Caucasian and African women's myoma uteri (4.81 kPa), but slightly higher than the bright (high) T2-weighted signal intensity of myoma uteri (2.88 kPa)[11]. Obrzut et al. also presented the mean stiffness of myoma uteri at 3.36±1.21 kPa, which was higher than the present results[17]. Uterine sarcomas seemed to have less fibrotic tissue, which referred to an unusual type of myoma uteri with premalignant potential[18]. The prevalence of uterine cancer in Thai women was only one-third that of USA women (39.64 versus 144.28 per 100,000)[19].

The MRE was not useful when calcification occurred within the myoma uteri. The current software cannot be used to calculate its stiffness value of the calcium component.

Conclusion

Uterine MRE is a useful non-invasive reproducible diagnostic tool for evaluating tissue stiffness of the myoma uteri, which is higher than normal uterine tissue. The mean stiffness of Thai patient myoma uteri was lower than other races.

What is already known on this topic?

MRI offers a comprehensive map of the uterus including the site, size, distribution of focal uterine masses, and further characterization. Although sonography is usually the first-line imaging study, the enlarged uterus limits its usage. The stiffness of myoma uteri can be obtained by TVUE, but the procedure itself might cause uneasiness to the patients.

What this study adds?

MRE takes only five minutes more than the standard MRI. The MRE should be more comfortable than TVUE.

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Conflicts of interest

The authors declare no conflict of interest.

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