Taiwanese Journal of Obstetrics & Gynecology 55 (2016) 646–649

Contents lists available at ScienceDirect

Taiwanese Journal of Obstetrics & Gynecology

journal homepage: www.tjog-online.com

Original Article

A retrospective study of magnetic resonance-guided focused ultrasound ablation for uterine myoma in Taiwan

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ARTICLE INFO

Article history:
Accepted 16 March 2015

Keywords:
magnetic resonance-guided focused ultrasound surgery (MRFUS)
quality of life score (QOLS)
Symptom Severity Score (SSS)
uterine fibroids

ABSTRACT

Objective: To report our experiences with 40 patients who were treated with magnetic resonance-guided focused ultrasound surgery (MRgFUS) for uterine fibroids and their 6-month follow-up status.
Materials and Methods: A total of 40 patients with uterine fibroids underwent MRgFUS from January 2009 to November 2011. The Uterine Fibroid Symptoms and Quality of Life Questionnaire was used to determine the patients' Symptom Severity Scores (SSS) prior to and 6 months after treatment. The nonperfused volume (NPV) values and NPV ratio were obtained immediately at the end of the treatment and at 6 months follow-up.
Results: No procedure-related complications were noted throughout the 6-month follow-up period among the 40 patients who underwent MRgFUS for uterine fibroids. The mean reduction in SSS in our patients after 6 months was 43.7%, and the mean reduction of fibroid volume was 31.7%. In addition, the mean reduction of NPV and mean NPV ratio was 52.7% and 33.3%, respectively.
Conclusion: The results obtained from this study demonstrated that MRgFUS can be safely and effectively used to ablate uterine fibroids to produce a significant decrease in mean fibroid volume and improve SSS for up to 6 months after treatment.

Introduction

Uterine leiomyomas (fibroids) are the most common benign neoplasm that can occur in reproductive-age women. About 20–50% of reproductive-age women have uterine myoma, whereas many women do not experience any problems. About 10% of reproductive-age women with myoma suffer from symptoms that affect their quality of life. Generally, fibroids have been identified clinically in at least 25% of women [1]. Furthermore, pathologic analysis suggests that the prevalence of fibroids may be as high as 77% [2,3]. In the past, surgical procedures such as myomectomy or hysterectomy were the traditional treatment for symptomatic uterine myoma. However, more and more women have chosen not to undergo invasive treatments because of postoperative complications. In 2004, the United States Food and Drug Administration approved magnetic resonance-guided focused ultrasound ablation (MRgFUA), the least invasive therapy for uterine myoma aside from oral therapy. Since then, MRgFUA has been used worldwide to treat symptomatic uterine myomas [4–6].

Focused ultrasound generates heat by focusing ultrasound waves to ablate tissue only at the focal point. This effect is similar to a magnifying glass that uses focused sunlight to burn a leaf. The high-intensity ultrasound deposits localized energy, causing rapid vibration of molecules within the focal spot, where the focal point temperature can rise to 60–80°C, resulting in thermal ablation within a small tissue region (about 1–2 mL). After repeating several adjacent small region ablations, larger volumes of ablation can be performed gradually. The required number of sonications and the length of the treatment depend on the size of the fibroid. The time required for the entire magnetic resonance-guided focused ultrasound surgery (MRgFUS) ranges from 2 to 3 hours. This noninvasive procedure is a new treatment for uterine fibroid, because more and more patients do not wish undergo any surgical incision, puncture of the uterus, anesthesia, or radiation exposure [7]. Many reports from the United States, Europe, Japan, and Korea have confirmed the safety and effectiveness of the procedure, and it is considered

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http://dx.doi.org/10.1016/j.tjog.2015.03.011

unique in the sense that only the targeted areas are affected, leaving the surrounding tissue unharmed [8,9].

In Taiwan, there is less experience of using MRgFUS in treating uterine myoma in recent years when compared to other countries. This paper demonstrates our experiences and the result of a 6-month follow-up of 40 patients (from January 2009 to November 2011), who underwent MRgFUS treatment for uterine myoma.

Materials and methods

From January 2009 to November 2011, a total of 400 patients sought MRgFUS treatment for their symptomatic uterine fibroids in our hospital. All patients were required to complete the Symptom Severity Score (SSS) and Uterine Fibroid Symptoms and Quality of Life (UFS-QOL) questionnaires [10] (Table 1) for the assessment of uterine fibroid symptoms. These patients underwent initial magnetic resonance imaging (MRI) scans for fibroid screening using a 1.5-T MRI scanner (GE Medical Systems, Milwaukee, WI, USA) with T1-weighted, T2-weighted, and enhanced T1-weighted (axial, coronal, and sagittal) sequences. In this MRI screening, the exclusion criteria were as follows: fibroids larger than 10 cm or smaller than 3 cm, fibroid number is more than four, fibroids located on the subserosal layer of the uterus, fibroids with hyperintensity (white fibroid) on T2-weighted images, necrotic fibroids, extensive adenomyosis, and extensive abdominal scar that obstructs the ultrasound beam path [3]. According to the screening MR images, 124 patients (31%) were suitable for MRgFUS treatment under our criteria, of which only 40 patients (10%) chose to undergo MRgFUS for fibroids treatment.

During the treatment, the patient's lower abdomen was shaved and cleaned to remove any hair. An intravenous (IV) line was set up for administration of sedatives, and a urinary catheter was inserted to empty the urinary bladder. The patient laid prone on the ExAblate 2000 treatment table (InSightec, Haifa, Israel), in which the transducer is housed. The patient's legs may be wrapped with compression stockings to reduce the risk of deep vein thrombosis. Prior to treatment initiation, 10 mg diazepam *per os* and 2 mL fentanyl via IV were given for sedation. The patient's blood pressure, heart rate, oxygenation, and comfort level were monitored throughout the treatment. The position of the patient over the transducer is determined from the three-plane localizer, T2-weighted image. To avoid ultrasound energy-sensitive regions such as bone, bowel, and nerves, these regions were marked to ensure safety (Figures 1A and 1B). At the end of the MRgFUS ablation treatment, a series of contrast-enhanced T1-weighted images were acquired to determine the treatment outcome, where the treated fibroid would be shown as a nonperfused area. The therapeutic effect was then determined by the change in nonperfused volume (NPV) calculation. The NPV percentage of the fibroids was calculated as NPV divided by total fibroid volume and multiplied by 100 [3]. After these postprocedure assessments, the patients were sent to a recovery room with their accompaniment and may be discharged within an hour.

All patients were required to return for follow-up MRI examinations, 6 months after the MRgFUS treatment. Prior to the follow-up examinations, they were asked to complete additional follow-up SSS and UFS-QOL questionnaires as well. The total fibroid volume and the NPV change ratio were calculated using the same method based on T2-weighted images and enhanced T1-weighted images.

Table 1
Symptom Severity Score (SSS) questionnaire.

During the previous 3 mo, how distressed were you by	SSS				
	1	2	3	4	5
1. Heavy bleeding during your menstrual period					
2. Passing blood clots during your menstrual period					
3. Fluctuation in the duration of your menstrual period compared to your previous cycle					
4. Fluctuation in the length of your monthly cycle compared to your previous cycle					
5. Feeling tightness or pressure in your pelvic area					
6. Frequent urination during the daytime hours					
7. Frequent nighttime urination					
8. Feeling fatigued					
Total score					

Scores: 1 = not at all; 2 = a little; 3 = somewhat; 4 = a great deal; 5 = a very great deal.

Results

The mean age of the 40 patients was 41.9 ± 4.5 years (range, 35–51 years). No serious or unexpected adverse events occurred during the 6-month-long study. All patients were followed up for 6 months, and no procedure-related complications were recorded throughout this period. The SSS and UFS-QOL prior to and after treatment for 6 months are shown in Table 2. The total fibroid volume and the NPV ratio prior to and after treatment for 6 months are shown in Table 3 (Figures 2 and 3).

Discussion

Uterine fibroid is a benign tumor that arises from the muscle tissue of the uterus, and the size of the myoma varies from as large as a melon to as small as a coin. Approximately 20–50% of reproductive-age women develop uterine myoma, whereas many women do not experience any similar symptoms that require treatment. About 10% of reproductive-age women with myoma have severe symptoms that affect their quality of life. For example, the complication of a large myoma may cause very heavy and prolonged menstrual periods, pain in the back of the legs, pelvic pain or pressure, pain during sexual intercourse, constipation, increased urinary frequency, incontinence, and the inability to empty the bladder [3,11–13]. Sometimes, a woman with an enlarged abdomen because of a large fibroid would be mistakenly assumed to have gained weight or to be pregnant. The patients have several options for treatment for uterine fibroid, including hysterectomy, myomectomy (abdominal or laparoscopic), uterine artery embolization, and hormonal therapy [14]. In addition, there are imaging-guided ablation methods that destroy the structure of myomas while sparing normal tissue; these include laser ablation, cryoablation, radiofrequency ablation, and MRgFUS [15,16]. Each of the treatments has its own benefits and disadvantages, and each one has varying degrees of invasiveness for the treatment of symptomatic uterine fibroids.

The combination of ultrasound and MRI (MRgFUS) provides an alternative noninvasive treatment for uterine fibroids. In a study performed by Sapareto and Dewey [17], the tumoral tissue was damaged when the thermal exposure is higher than the tissue's thermal threshold. The 100% focal tissue damage of thermal dosimetry is under 43°C for 240 minutes of treatment duration (time–temperature relationship). The time–temperature relationship upon which this equivalent dose calculation is based does not predict nor require that different tissues have the same sensitivity to heat. So the equivalent thermal dosimetry for 100% tumoral tissue damage is determined to be 54°C for 3 seconds or 57°C for 1 second [17]. High-intensity focused ultrasound waves are used to noninvasively heat and thermally destroy the fibroid, whereas magnetic resonance imaging (MRI) provides anatomical imaging guidance during treatment planning and is used in real time for thermal monitoring during the treatment. Postprocedural MRI

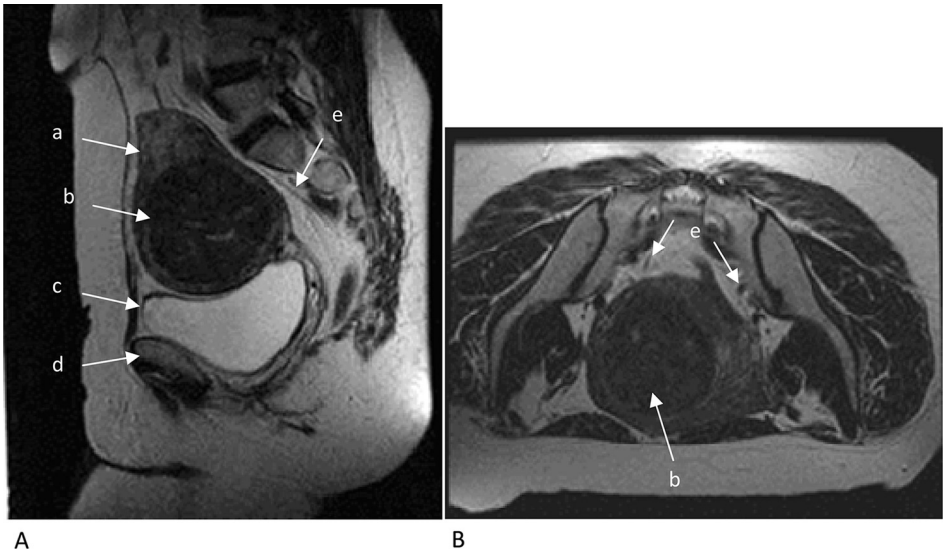

Figure 1. (A) T2-weighted sagittal scan image. (B) T2-weighted axial scan image for preprocedure planning. The sensitive regions such as pubic bone, bowel and nerves (arrows) were marked to ensure safety of MRgFUS ablation. a = uterus; b = uterine fibroid; c = urinary bladder; d = pubic bone; e = sacral nerve. MRgFUS = magnetic resonance-guided focused ultrasound surgery.

Table 2
SSS of patients prior to and 6 months after treatment.

	Pre-MRgFUS	Post-MRgFUS in 6 mo	Change
SSS (8 questions)	62.2 ± 16.4	35.0 ± 9.5	−43.7%
UFS-QOL (29 questions)	37.9 ± 15.8	57.0 ± 13.6	+33.5%

MRgFUS = magnetic resonance-guided focused ultrasound surgery; SSS = Symptom Severity Score; UFS-QOL = Uterine Fibroid Symptoms and Quality of Life Questionnaire.

Table 3
Fibroid size, NPV, and NPV ratio of patients at baseline and 6 months after treatment.

	Pre-MRgFUS	Post-MRgFUS in 6 mo	Change
Size	258.1 ± 223.8	176.2 ± 164.2	−31.7%
Nonperfused volume (NPV)	149.2 ± 112.7	70.6 ± 65.2	−52.7%
NPV ratio	64.5 ± 11.4	43.0 ± 26.6	−33.3%

MRgFUS = magnetic resonance-guided focused ultrasound surgery; NPV = nonperfused volume.

assessment was performed after the administration of a gadolinium contrast to determine the extent of MRgFUS treatment.

During MRgFUS therapy, the ultrasound beam is focused on the fibroid tissue, and because of the significant energy deposited at the focus (sonication), the temperature within the tissue rises to between 65°C and 85°C, destroying the fibroid tissue via coagulation necrosis [18]. This is the reason why the fibroid volume decreased significantly in our study after 6 months. We suggest that the reduction in fibroid volume is closely associated with the improvement of SSS (the SSS mean scores decreased from 62.2 ± 16.4 to 35.0 ± 9.5) and UFS-QOL (the UFS-QOL scores improved from 37.9 ± 15.8 to 57.0 ± 13.6). We conclude that MRgFUS is effective in reducing fibroid volume and providing relief for myoma symptoms. Furthermore, the ideal therapeutic effect of the NPV ratio is 55 ± 25% immediately after treatment [19].

In this study, MRgFUS was determined to be effective in improving symptom severity, 6 months after treatment. The average SSS prior to the treatment was 62.2 ± 16.4. The SSS reduced to 35.0 ± 9.5 at 6 months after the treatment. The mean reduction

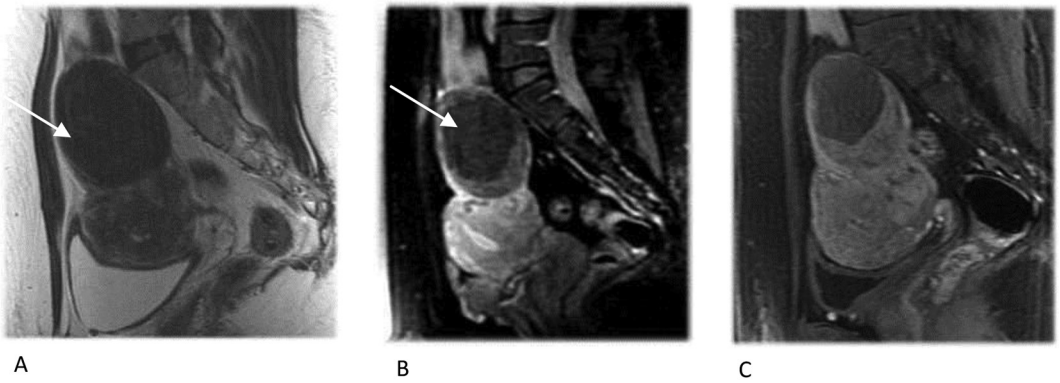

Figure 2. (A) Pretreatment T2-weighted sagittal image of a 44-year-old woman demonstrating one uterine fibroid (arrow) measuring about 97 mL (volume). Her SSS and UFS-QOL is 40.6 and 64, respectively. (B) Posttreatment enhanced T1-weighted image of the patient demonstrating the resulting NPV ratio (53.6%). The low signal intensity area (arrow) is indicative of the posttreatment necrotic area. (C) The 6-month follow-up enhanced T1-weighted image demonstrating the volume of fibroid decreased to 61.2 mL. The volume decrease rate is 36.9%. The SSS and QOL is 9.3 and 89.7, respectively. The improvement of SSS and UFS-QOL is 31.3 and 25.7, respectively. NPV = nonperfused volume; SSS = Symptom Severity Score; UFS-QOL = Uterine Fibroid Symptoms and Quality of Life Questionnaire.

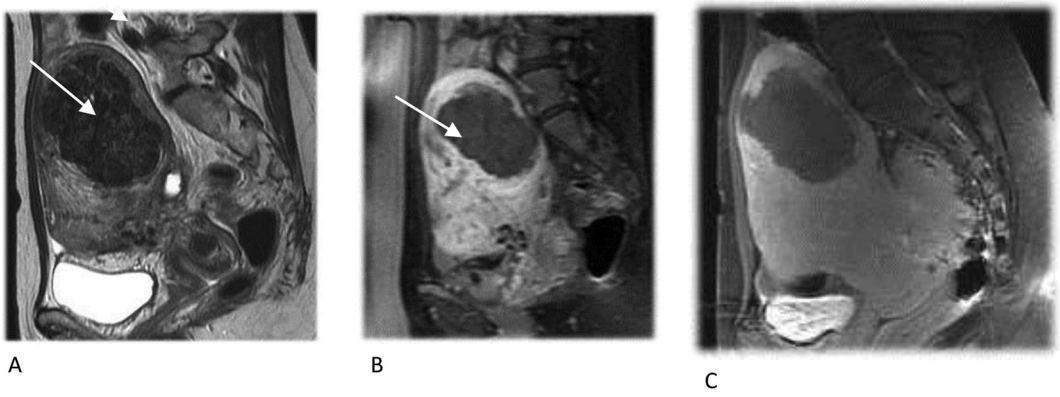

Figure 3. (A) Pretreatment T2-weighted sagittal image of a 47-year-old woman demonstrating one uterine fibroid (arrow) measuring about 150.2 mL (volume). Her SSS and UFS-QOL is 53.1 and 29.3, respectively. (B) The posttreatment enhanced T1-weighted image of the patient demonstrating the resulting NPV ratio (66.7%). The low signal intensity area (arrow) is indicative of the posttreatment necrotic area. (C) The 6-month follow-up enhanced T1-weighted image demonstrating that the volume of fibroid decreased to 89.3 mL. The volume decrease rate is 40.5%. The SSS and QOL is 37 and 61, respectively. The improvement of SSS and UFS-QOL is 16.1 and 31.7, respectively. NPV = nonperfused volume; SSS = Symptom Severity Score; UFS-QOL = Uterine Fibroid Symptoms and Quality of Life Questionnaire.

rate in SSS in our patients after 6 months was 43.7% (Table 2), which is similar to the results reported by earlier studies [20–22]. In addition, the mean fibroid volume was reduced from 258.1 to 176.2 mL (31.7% reduction rate), and the mean NPV was reduced from 149.2 to 70.6 mL (52.7%) (Table 3). These results are also very similar to previous published results [23–25]. These results demonstrate that MRgFUS is an effective method for the selective ablation of tissue within the uterus, and this noninvasive treatment may be offered as an alternative therapy for women with uterine fibroids.

This is the first retrospective study of MRgFUS for treatment of uterine fibroids in Taiwan. Our results demonstrated that MRgFUS can be safely and effectively used to ablate sufficient uterine fibroids to produce a decrease in mean fibroid volume and significantly improve SSS for up to 6 months. However, further investigation is still required to determine the potential fertility impact and pregnancy outcome of these patients in the future.

Conflict of interest

The authors have no conflicts of interest relevant to this article.

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