Uterine Artery Embolization for Leiomyomas: Examination of Correlation Between Degree of Leiomyoma Perfusion Determined by Enhanced MR i-Drive Method and Leiomyoma Volume Change on MR Image

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Key Words : uterine artery embolization, uterine leiomyoma, MR i-Drive method

ABSTRACT

Objectives: To evaluate the correlations of leiomyoma volume reduction with the perfusion pattern of leiomyomas and signal intensity on T2-weighted images.

Methods: Magnetic resonance (MR) imaging was performed on 11 patients with 35 symptomatic uterine leiomyomas before and 3 and 6 months after uterine artery embolization (UAE). The correlation between leiomyoma perfusion pattern and percent leiomyoma volume reduction was assessed.

Results: The mean percent leiomyoma volume reductions were 41.1% 3 months and 58.4% 6 months after UAE. The mean percent volume reductions of highly perfused leiomyomas were 58.6% 3 months and 85.7% 6 months after UAE. The reduction rates of poorly perfused leiomyomas were 37.9% 3 months and 49.1% 6 months after UAE.

Conclusions: Well-perfused leiomyomas are more likely to reduce in leiomyoma volume. It is thought that a patient with a well-perfusion myoma is a good candidate for UAE.
the correlation between the perfusion pattern of leiomyomas using the enhanced MR i-Drive method and their volume reduction rates, and that between the improvement of complaints and their volume reduction rates.

**MATERIALS and METHODS**

From April 2002 to October 2003, we performed UAE in Osaka Medical College Hospital on 11 consecutive female patients (35 uterine leiomyomas) who had symptomatic myomas (with symptoms such as menorrhagia and severe anemia, and bulk-related symptoms). Internal medical therapy proved ineffective for the patients and they refused to undergo surgery. The patients were from 35 to 47 years old (mean age, 41.7 years ± 5.04 [SD]) and were menstruant. The Osaka Medical College Ethics committee approved of the use of UAE, and informed consent was obtained from the patients before performing UAE, after the possible complications were explained.

We used a Signa MR/I EchoSpeed 1.5T CV/NV Option (GE). MR imaging was performed before and 3 and 6 months after UAE. MR imaging consisted of axial and sagittal T1-weighted images, T2-weighted images, and gadolinium-enhanced sequences using the i-Drive method (imaging parameters: minimum minimum full FA80 BW=62.5kHz, 256 × 128, slice thickness=5mm) (Figure 1). Gadodiamide was used at 0.5 mmol per kilogram of body weight. It was injected into a vein at 3 ml/sec and dispersed with 10 ml of saline. We used a 5-F cobra catheter (Clinical Supply, Gifu, Japan), TYPE-TAKI (Medikit, Tokyo, Japan), and a 5-F MOHRI catheter (Clinical Supply, Gifu, Japan). Embolization was performed using the right femoral artery approach, and both uterine arteries were catheterized in the all patients. Embolization was achieved by injecting how much of 1-mm gelatin sponge particles (Yamanouchi, Tokyo, Japan) into each uterine artery until blood flow ceased [5,6]. Epidural anesthesia was induced in all the patients and pain was controlled. Moreover, an additional injection of a Diclofenac-Na suppository and Pentazocine 1A into the muscles of the humerus was given out when necessary.

We determined whether leiomyoma volume reduction rate correlates with leiomyoma perfusion pattern, signal intensity on T2 weighted images (hyperintensity or hypointensity), and leiomyoma location (submucosal or intramural). Leiomyoma volume was measured using the formula length × width × depth × 0.5233 as a prolate ellipse. Leiomyoma volume reduction rate was defined as

\[(\text{Vpre-Vpost})/\text{Vpre} \times 100\%\] (Vpre, volume before UAE; Vpost, volume after UAE). The leiomyoma signal intensities on T2 weighted images were classified into the hypointensity group (types 1 and 2) and hyperintensity group (types 3 to 5), according to Oguchi's classification [7]. In Oguchi's classification, on T2-weighted imaging, according to the increase of signal intensity relative to that of the myometrium and/or the endometrium, they can roughly classify them into five major images.

Leiomyoma location was classified as submucosal, intramural, subserosal, or cervical. We observed the perfusion patterns of 12 uterine leiomyomas (from 6 patients) using the enhanced MR i-Drive method before and 3 and 6 months after UAE. The observation was performed by scanning each section for 1 sec (Figure 2, 4). Moreover, the regions of interest (ROIs) were drawn over a maximally enhanced area within each leiomyoma and the myometrium, and a dynamic curve was obtained [8] (Figure 3, 5). The uterine leiomyomas were characterized into diffuse dark when the slope of the dynamic curve and the degree of leiomyoma enhancement were respectively equivalent to or greater than those for the adjacent myometrium, and diffuse light when the slope of the dynamic curve and the degree of leiomyoma enhancement were less than those for the adjacent myometrium. Clinical symptoms before and 6 months after UAE were assessed by evaluating the severities of menorrhagia and bulk-related symptoms, which were caused by uterine leiomyomas. The severities were scored from 1 to 5. All the patients completed a questionnaire concerning their symptoms after UAE, and their

**Fig. 1** We show one case. The patient was 38 years old. The chief complaints were menorrhagia, anemia. On T2-weighted images (left side), the nodule showed heterogeneous hyperintensity, predominantly more than that of the surrounding myometrium. Contrast-enhanced images (right side) showed a heterogeneous enhancement similar to the myometrium.
responses to questions regarding (1) menorrhagia and (2) bulk-related symptoms were stratified as follows: excellent, 5; better, 4; slightly good, 3; no change, 2; worse, 1. We classified patients who scored more than 8 points into the high-score group, and patients who scored less than 7 points into the low-score group.

Statistical analyses were done by using software (STATISTICA, Stat Soft Ltd, Tokyo, Japan), and paired t-test was performed. It was defined that it was significant difference if p-values were less than 0.05.

The above-mentioned data analysis was performed by two radiologists.

RESULTS

The embolization was successful for all case. After UAE, non-enhanced leiomyoma volume decreased in all the patients. Three and 6 months after UAE, the leiomyoma volume further decreased from their preprocedural values by 41.1% and 58.4%, respectively (Figure 6).

One of the 11 patients, despite her lack of critical complications, showed an infected endometrium. This patient had a submucosal leiomyoma. Three weeks after UAE, symptoms such as increased vaginal discharge, abdominal pain, and fever were noted; thus, the patient was rehospitalized.

In each perfusion pattern, reduction rate was evaluated. When the slope of the myometrium was compared with that of the leiomyoma nucleus, at a larger slope of the leiomyoma nucleus, we found that each leiomyoma was more highly perfused than the myometrium; however, at a smaller inclination of the leiomyoma nucleus, each leiomyoma was more poorly perfused than the myometrium. Before UAE, of the 12 leiomyomas whose perfusion patterns decreased in all the patients. Three and 6 months after UAE, the leiomyoma volume further decreased from their preprocedural values by 41.1% and 58.4%, respectively (Figure 6).

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were observed, 7 were diffuse light and 5 were diffuse dark. Three and 6 months after UAE, the volumes of the diffuse light leiomyomas decreased from their preprocedural values by 37.9% and 49.1%, and those of the diffuse dark leiomyomas decreased by 58.6% and 85.7%, with p-values of 0.0399 and 0.0375, respectively (Figure 7). By the i-Drive method after UAE, 33 of the 35 leiomyomas showed no enhancement, and leiomyomas that were not perfused exhibited a decrease in volume in all the patients. Embolization was completely achieved for both uterine arteries, but the perfusion of the myometrium in all the patients completely normalized 3 months after UAE (Figure 5).

At each signal intensity on T2-weighted images, the reduction rate was evaluated. Before UAE, the hypointensity group consisted of 23 of the 35 leiomyomas and the hyperintensity group consisted of the remaining 12. On T1-weighted images, a hyperintensity rim surrounding the leiomyomas was observed after UAE. This hyperintensity rim on T1-weighted images corresponds to the hypointensity rim on T2-weighted images at the periphery of each myoma. In each group, the reduction rates 3 and 6 months after UAE were calculated. Three and 6 months after UAE, the leiomyoma volumes in the hypointensity group decreased from their preprocedural values by 35.4% and 52.5%, and those in the hyperintensity group decreased by 50.8% and 69.2% with P-values of 0.0017 and 0.0395, respectively (Figure 8).

In each leiomyoma location, reduction rate was evaluated. The locations of the leiomyomas were submucosal in nine, intramural in 22, subserosal in two, and cervical in two. Three months after UAE, the volumes of the intramural leiomyomas decreased from their preprocedural values by 36.5%, and those of the submucosal leiomyomas decreased by 56.4% with a P-value of 0.0004. Six months after UAE, the volumes of the intramural leiomyomas decreased by 51.3% and those of the submucosal leiomyomas decreased by 85.7% with a p-value of less than 0.0001 (Figure 9).

The mean leiomyoma volume reduction rates of the patients in the high-score group were 52.0% 3 months and 79.0% 6 months after UAE. Those of the patients with a low score on the questionnaire were 32.6% 3 months and 49.5% 6 months after UAE (Figure 10).
The thickness of the endometrium was measured before and 3 months after UAE. From a sagittal T2 weighted image, the endometrium was examined, and its thickest portion was measured without considering the menstrual cycle. The average endometrium diameters were 7.3 mm before UAE, and 5.3 mm 3 months after UAE. In no case, the thickness of the endometrium after UAE was larger than that before UAE (Figure 11).

DISCUSSION

In two studies, leiomyoma volume reduction rates 3 and 6 months after UAE were evaluated. There was a statistically significant difference between the reduction rates for two perfusion patterns (diffuse light and diffuse dark) 3 and 6 months after UAE. As expected, the volume of more highly perfused leiomyomas decreased. However, no significant difference between the leiomyoma volume reduction rates of the two perfusion patterns has been reported elsewhere [8,9]. Jha, et al [10] reported that hypervascular leiomyoma is a strong predictor of success of UAE because their result is consistent with the embolization theory, namely, embolic particles are delivered to regions of high blood supply, where such particles produce the strongest effect. Regions of hypervascularity, in principle, have a lower impedance to blood flow; thus, they act as sinks for UAE particles. Burn et al [9] reported that an increased contrast enhancement of a leiomyoma is presumably indicative of a lesion with increased vascularity and predictive of a higher effectiveness, although this was not confirmed in our study. We consider that the marked difference between these results is due to how ROI was drawn. It is considered possible that the degree of perfusion appears smaller than that when a large ROI is drawn on a leiomyoma because leiomyomas cause mucinous degeneration, and edema and mucinous degeneration partly enhance the induction of light leiomyomas [11,12]. However, the degeneration of leiomyomas is thought to depend on an insufficient supply of blood to the...
growing leiomyoma, and to be an index of activity. Therefore, to determine the actual degree of perfusion independent of the degenerating part, we consider that ROI should be drawn on the leiomyoma part with the highest degree of perfusion. For this reason, we used the enhanced MR i-Drive method and accurately drew ROI on the leiomyoma part where the degree of perfusion was visually the largest.

Most leiomyomas were decreased in volume without regrowth when they were infarcted [7,17]. It is necessary that we evaluate a leiomyoma perfusion before and after UAE because the perfusion and prognosis closely correlate to each other. For such reasons, i-Drive method was useful that we could evaluate a leiomyoma perfusion.

There was also a statistically significant difference between the reduction rates of two signal intensity groups on T2-weighted images 3 and 6 months after UAE. As expected, the leiomyoma volume of the hyperintensity group on T2-weighted images decreased. Many studies have shown that hyperintensity on T2-weighted images is predictive of leiomyoma volume reduction [8,9,12,13]. The result of our study is consistent with this notion. Okizuka, et al [12], reported that degenerative changes in leiomyomas may be due to inadequate blood supply, and that the type of degenerative change seems to depend on the degree and rapidity of the onset of vascular insufficiency. When a leiomyoma enlarges, oxygen deprivation will lead to degenerative changes because blood supply to the tumor tissue becomes inadequate. The following can be deduced from those results. The presence of a number of hyperintense edematous leiomyomas on T2-weighted images indicates tumor activity. Moreover, it is considered that the degree of perfusion is reflected by tumor activity. Therefore, it is considered that an active leiomyoma exhibits a large effect of leiomyoma volume reduction when blood flow is stopped. It is also considered that such a large effect is not necessarily obtained without activity even if a leiomyoma is large.

There was a significant difference between the volume reduction rates of the intramural and submucosal leiomyomas 3 and 6 months after UAE. As expected, the volumes of the submucosal leiomyomas decreased. Jha and other [9,10,13,14] reported that a submucosal leiomyoma location strongly correlates with a positive outcome. In our study, all the submucosal leiomyomas had well-marked perfusion, which could be one reason for the large reduction effect observed. We have thus far encountered one patient with infection from a submucosal leiomyoma after UAE. This possibility must be taken into consideration to prevent infection after UAE. It is previously reported that infection frequencies after UAE range from 1 to 2% [15].

Recently, pregnancy after UAE has been considered a clinical problem. There have been some reports on pregnancy and delivery after UAE. In our hospital, we encountered a patient who became pregnant after UAE, and the conditions of the patient and embryo were normal. It has been reported that the endometrium after UAE was thin in 9 of 11 patients, and that endometrial damage is associated with diseases such as Asherman’s syndrome. McCluggage reported that in some patients, particularly those with large submucosal leiomyomas, the necrosis of the endometrial surface and the surface’s replacement by granulation tissue occurred after UAE [1]. Therefore, the use of UAE in a patient who wishes to become pregnant must be considered carefully [1,15,16,17].

We have encountered two patients with cervical uterine myomas. One patient underwent bilateral UAE. The angiogram obtained immediately after UAE showed no bilateral uterine artery or tumor stain, but 3 months after UAE, no signal intensity changes within the cervical leiomyoma were observed on T1-weighted or T2-weighted images, and the entire leiomyoma was enhanced on the enhanced MR i-Drive method [18,19]. The uterine cervical leiomyoma volume hardly decreased. One reason for the refractory nature of this cervical leiomyoma was the origin of the blood flow, which included a descending and vaginal branch unlike the blood vessel supplying a typical leiomyoma. The other patient underwent unilateral UAE with dilatation. The partially necrosed myoma and its residual portion showed regrowth after one year. The anastomotic blood supply between both uterine arteries is the cause of the unsuccessful treatment by unilateral embolization [20]. Treating cervical leiomyoma is difficult. Because vaginal necrosis may take place if embolism is induced in the cervical branch, it is necessary to carry out the medical treatment carefully. It is considered that the treatment of a cervical leiomyoma by UAE is difficult, compared with that of a typical leiomyoma.

In this study, leiomyoma volume showed a decreasing tendency, and there was a decrease in the number of complaints concerning symptoms such as menorrhagia and bulk-related symptoms. UAE is an effective therapy for managing symptomatic leiomyomas [21]. In our study, we did not found a significant difference. Most studies showed that there are no significant differences between patients’
symptoms like menorrhagia and bulk-related symptoms and the volume reduction rate of leiomyomas [13,22,23].

It was expected that there is a close relationship between the degree of leiomyoma perfusion and leiomyoma volume reduction rate. Therefore, if UAE is performed successfully and the reduction rate is large, it is thought that the degree of perfusion will decrease greatly and lead to symptom improvements. However, our result was different from those of many studies. It should be emphasized that this is a small study and should be duplicated with a larger number of patients.

CONCLUSION

As a method of determining the degree of leiomyoma perfusion, the enhanced MR i-Drive method used in this study has been proved to be useful. And before and after UAE, MR imagings with i-Drive method were important for us to prognose.

It is also considered that UAE may be effective for treating hyperintense leiomyomas on a T2-weighted images in addition to well-perfused.

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Received June 15, 2007
Accepted August 24, 2007