Uterine Fibroleiomyoma: MR Imaging Appearances before and after Embolization of Uterine Arteries[1]

Paul R. Burn, FRCR
James M. McCall, FRCR
Roger J. Chinn, FRCR
Arvind Vashisht, MRCOG
J. Richard Smith, FRCOG
Jeremiah C. Healy, FRCR

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[1] From the Department of Radiology, Chelsea and Westminster Hospital, London, England. From the 1998 RSNA scientific assembly. Received February 17, 1999; revision requested March 17; revision received June 3; accepted June 15. **Address reprint requests to** P.R.B. 39 Hanover Gardens, Oval, London NE 11 5TN, England. (e-mail: *paulburn@lesbaux.demon.co.uk*).

Author contributions:
Guarantor of integrity of entire study, J.C.H.; study concepts, J.C.H., R.J.C., J.R.S.; study design, J.C.H., R.J.C., J.M.M.; definition of intellectual content, J.C.H., R.J.C.; literature research, P.R.B.; clinical studies, J.C.H., R.J.C., J.M.M.; data acquisition, J.C.H., R.J.C., P.R.B.; data analysis, P.R.B.; statistical analysis, P.R.B.; manuscript preparation, P.R.B.; manuscript editing, P.R.B., J.C.H.; manuscript review, J.C.H., R.J.C., J.M.M., J.R.S., A.V.

PURPOSE: To evaluate the magnetic resonance (MR) imaging appearances of uterine fibroleiomyoma before and after embolization and to determine whether there are preembolization MR imaging characteristics that are predictive of a successful outcome.

MATERIALS AND METHODS: MR imaging was performed in 18 patients (32 fibroleiomyomas) before and at 2 and 6 months after embolization of the uterine arteries. On each occasion, fibroleiomyoma signal intensity and gadolinium enhancement characteristics were assessed in comparison with those of myometrium on T1-weighted and gadolinium-enhanced images or with those of skeletal muscle on T2-weighted images. Fibroleiomyoma volume was measured by using the ellipsoid formula.

RESULTS: The mean fibroleiomyoma volume before embolization was 340 cm^3 (range, 15–1,383 cm^3). The mean reduction in fibroleiomyoma volume was 43% at 2 months and 59% at 6 months. Before embolization, high signal intensity on T1-weighted images was predictive of a poor response ($P = .008$), and high signal intensity on T2-weighted images was predictive of a good response ($P = .007$). The degree of gadolinium enhancement was not correlated with fibroleiomyoma volume reduction ($P = .46$).

CONCLUSION: MR imaging was useful for evaluation of changes in fibroleiomyoma volume after uterine arterial embolization. MR imaging characteristics of fibroleiomyomas before embolization can help predict subsequent response to treatment.

Radiologic embolization of the uterine arteries to treat uterine fibroleiomyoma is a relatively recently developed technique (1). The authors of four published series (2–5), which collectively involved over 300 patients, described a mean fibroleiomyoma volume reduction of 40%–70% after embolization. Both ultrasonography (US) and magnetic resonance (MR) imaging have been used for evaluation of fibroleiomyoma size; to our knowledge, however, MR signal intensity and contrast material enhancement features of fibroleiomyoma after embolization have not been previously described. The aims of this study were, therefore, to determine the MR imaging appearances of fibroleiomyoma before and after embolization and to identify factors that are predictive of a more successful outcome.

MATERIALS AND METHODS

Subjects

Eighteen consecutive women aged 28–53 years (mean age, 39 years) with symptomatic fibroleiomyoma (causing menorrhagia or abdominal distention or discomfort) in whom surgical resection would otherwise be considered were recruited by the gynecology department. The diagnosis of fibroleiomyoma had previously been confirmed with US findings. Informed consent was obtained from all patients. Approval for the study was granted by the hospital ethics committee.

Embolization Technique

Embolization was performed by an experienced interventional radiologist (J.M.M.). After aortoiliac angiography, selective catheterization of the uterine arteries was carried out, and embolization was achieved by deploying 350–500-μm-diameter polyvinyl alcohol particles (Contour Emboli, St Albans, England) and absorbable gelatin sponge material (Spongostan; Johnson & Johnson, Ascot, England) until flow distal to the embolization site had ceased. Bilateral embolization was performed in all but two patients. Unilateral embolization was electively performed in the first patient in our series, in whom a dominant uterine artery was present. Unilateral embolization also was performed in another patient in whom only one uterine artery could be cannulated due to intense arterial spasm in the contralateral vessel. The procedure was carried out after intravenous administration of a sedative, and subsequent pain was managed by means of a patient-controlled intravenous opiate pump.

Imaging Technique

MR imaging was performed the day before and at 2 and 6 months after embolization by using a 1-T unit (Magnetom Impact Expert; Siemens Medical Systems, Erlangan, Germany) equipped with a phased-array body coil. Glucagon (1 mg) was administered intramuscularly before the examination to reduce bowel peristalsis. Before and at 2 and 6 months after embolization, the following MR sequences were performed: (*a*) transverse, sagittal, and coronal T2-weighted turbo spin-echo imaging (4,000/99 [repetition time msec/effective echo time msec], 256 × 242 matrix, 220 × 220-mm field of view, 5-mm section thickness) and (*b*) sagittal T1-weighted two-dimensional fast low-angle shot imaging with fat saturation (180/4.8 [repetition time msec/echo time msec], 75° flip angle, 256 × 106 matrix, 300 × 300-mm field of view, 8-mm section thickness) before and after administration of gadodiamide (Omniscan; Nycomed Amersham, Buckinghamshire, England). For assessment of the uterine arteries, dynamic gadolinium-enhanced three-dimensional fast imaging with steady-state precession MR angiography (6.7/2.8, 30° flip angle, 256 × 140 matrix, 350 × 350-mm field of view, 90-mm slab thickness with 32 partitions for an effective section thickness of 3 mm) was performed after intravenous injection of 20 mL of gadodiamide (0.5 mmol/mL).

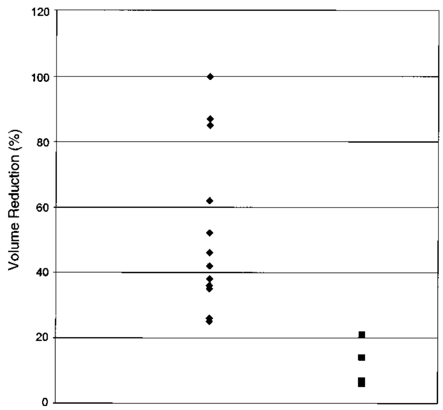


Figure 1. Graph shows the relationship between initial fibroleiomyoma signal intensity on T1-weighted MR images and subsequent postembolization percentage volume reduction. ◆ = fibroleiomyoma signal intensity lower than or equal to that of myometrium, ■ = fibroleiomyoma signal intensity higher than that of myometrium.

Image Analysis

All MR images were assessed by two experienced radiologists (J.C.H., R.J.C.), and a consensus was reached. On each image, the number and site(s) of fibroleiomyomas were recorded. On T2-weighted images, the signal intensity of fibroleiomyomas was assessed in comparison with that of skeletal muscle (higher, equal, or lower). On T1-weighted images, the signal intensity and contrast enhancement of fibroleiomyomas were assessed in comparison with those of adjacent myometrium (greater, equal, or less). Fibroleiomyoma volume was determined by measuring the maximum linear dimension in three planes and applying the ellipsoid formula (product of the three measurements × 0.52). In each patient, the largest fibroleiomyomas (maximum of four fibroleiomyomas per patient) were measured. Finally, the presence of each uterine artery was assessed by inspecting the MR angiographic images.

The relationship between signal intensity characteristics and total percentage volume reduction of fibroleiomyomas in each patient was analyzed. For each MR sequence, two groups were compared. On T1-weighted images, fibroleiomyomas with signal intensity lower than or equal to that of myometrium were compared with fibroleiomyomas with signal intensity higher than that of myometrium. On T2-weighted images, fibroleiomyomas with signal intensity higher than that of skeletal muscle were compared with fibroleiomyomas with signal intensity equal to or less than that of skeletal muscle. On

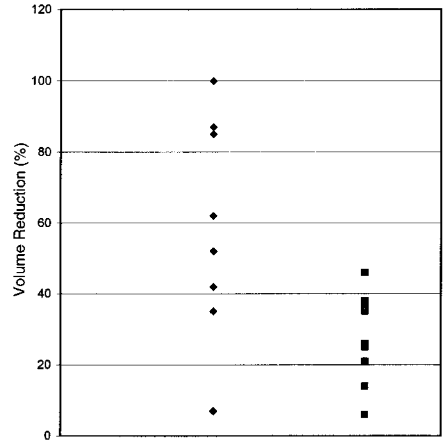


Figure 2. Graph shows the relationship between initial fibroleiomyoma signal intensity on T2-weighted MR images and subsequent postembolization percentage volume reduction. ◆ = fibroleiomyoma signal intensity higher than that of skeletal muscle, ■ = fibroleiomyoma signal intensity equal to or lower than that of skeletal muscle.

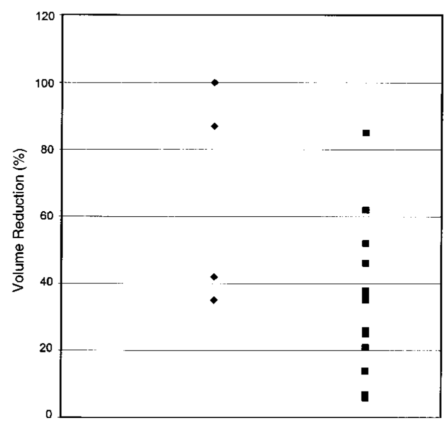
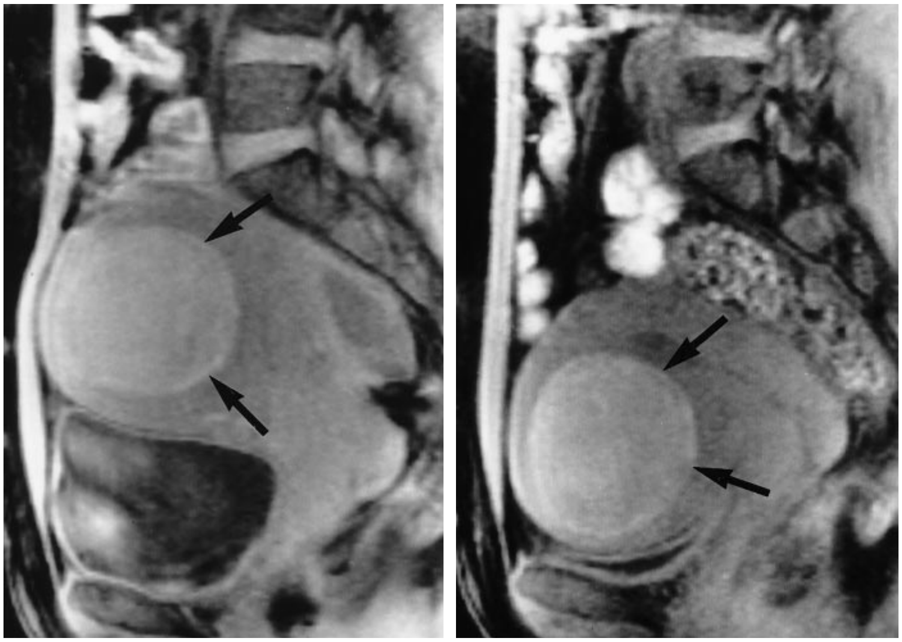


Figure 3. Graph shows the relationship between initial fibroleiomyoma contrast enhancement and subsequent postembolization percentage volume reduction. ◆ = fibroleiomyoma enhancement equal to or greater than that of myometrium, ■ = fibroleiomyoma enhancement less than that of myometrium.

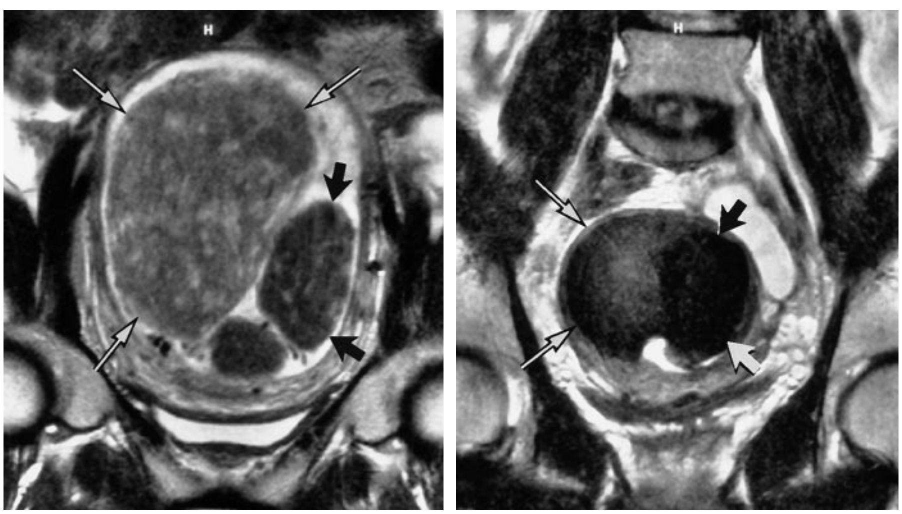
gadolinium-enhanced images, fibroleiomyomas with contrast enhancement that was greater than or equal to that of myometrium were compared with fibroleiomyomas with enhancement that was less than that of myometrium.

The adjusted geometric means of fibroleiomyoma volumes in the two groups were obtained by using linear regression on the log volumes as measured at 2 months after embolization (with the assumption of an initial fibroleiomyoma size of 230 cm^3, which was the geometric mean of all fibroleiomyomas in all pa-



a. b.

Figure 4. Sagittal T1-weighted two-dimensional fast low-angle shot MR images (180/4.8, 75° flip angle, 256 × 106 matrix, 300 × 300-mm field of view, 8-mm-thick sections) obtained **(a)** before and **(b)** after embolization show little change in fibroleiomyoma (arrows) volume. Thus, initial high signal intensity on T1-weighted images is predictive of a poor response to embolization.



a. b.

Figure 5. Coronal T2-weighted turbo spin-echo MR images (4,000/99 [effective], 256 × 242 matrix, 220 × 220-mm field of view, 5-mm-thick sections) obtained **(a)** before and **(b)** after embolization show that a large high-signal-intensity fibroleiomyoma (long arrows) undergoes a greater reduction in volume after embolization than does a low-signal-intensity fibroleiomyoma (short arrows).

TABLE 1
Volume of Fibroleiomyomas before and 2 Months after Embolization

	Total Volume (cm^3)		
Patient No.	Before Emboli-zation	After Emboli-zation	Volume Reduction (%)
1	172	83	52
2	108	102	6
3	362	210	42
4	481	231	52
5	243	209	14
6	216	32	85
7	269	172	36
8	27	0	100
9	28	15	46
10	321	122	62
11	310	233	25
12	1,383	899	35
13	690	642	7
14	742	460	38
15	434	343	21
16	654	484	26
17	15	2	87
18	323	210	35

tients, with fibroleiomyomas with an undetectable size assigned a volume of 1 cm^3). The ratios of the geometric means of the two groups were calculated for each MR sequence. This method was chosen because of the nonnormal distribution of fibroleiomyoma size and the possibility that percentage reduction is dependent on initial fibroleiomyoma size.

The mean percentage reduction in two defined groups, one with 16 larger fibroleiomyomas and the other with 16 smaller fibroleiomyomas, also were compared. The ratio of the geometric mean of the fibroleiomyoma volume before to that after embolization was calculated for each group by using linear regression on the log values, with robust variance clustered by patient.

Statistical analyses were carried out in conjunction with the hospital statistics department by using a statistical software package (STATA release 5.0; Statacorp, College Station, Tex).

RESULTS

Embolization was performed in 18 women. There were no important procedure-related complications. Deployment of a cannula in one uterine artery in one patient was unsuccessful due to arterial spasm. Altogether, 32 fibroleiomyomas were measured. The total fibroleiomyoma volume in each woman and the subsequent volume reduction are shown in Table 1.

The mean fibroleiomyoma volume before embolization was 340 cm^3 (range, 15–1,383 cm^3). The mean percentage reduction in fibroleiomyoma volume was 43% (range, 6%-100%) at 2 months and 59% (range, 6%–100%) at 6 months. The 16 larger fibroleiomyomas (preembolization volume range, 144–1383 cm^3) had a geometric mean volume reduction at 2 months of 40% (95% CI: 24%, 52%). The corresponding value for the 16 smaller fibroleiomyomas (preembolization volume range, 9–108 cm^3) was 60% (95% CI: 28%, 78%). The difference in reduction

TABLE 2
Change in Fibroleiomyoma Signal Intensity or Contrast Enhancement after Embolization in 17 Women

MR Sequence	Increase	No Change	Decrease
T1 weighted*	14	3	0
T2 weighted*	0	7	10
Gadolinium enhanced†	0	1	16

* Data are number of patients with or without change in fibroleiomyoma signal intensity.
† Data are number of patients with or without change in contrast enhancement.

between the two groups was not significant (P = .13). Patients with more than one fibroleiomyoma had a mean volume reduction of 43%; those with a single fibroleiomyoma had a volume reduction of 45%.

In one woman, the single fibroleiomyoma present disappeared following embolization. After embolization in the remaining 17 patients, there was an increase in fibroleiomyoma signal intensity on T1-weighted images in 14 (82%) women, a decrease in fibroleiomyoma signal intensity on T2-weighted images in 10 (59%), and reduced fibroleiomyoma contrast enhancement in 16 (94%) (Table 2).

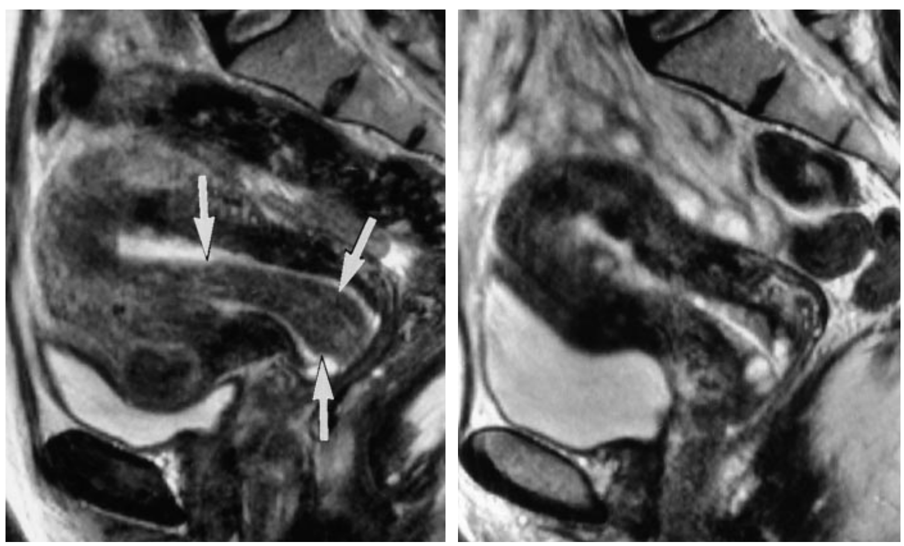
High signal intensity in fibroleiomyomas on MR images obtained before embolization was predictive of a poor response to subsequent embolization; the ratio of geometric means of the defined groups was 1.97 (95% CI: 1.23, 3.17; P = .008) (Fig 1). High signal intensity in fibroleiomyomas on T2-weighted images was predictive of a good response; the ratio of geometric means was 2.19 (95% CI: 1.29, 3.71; P = .007) (Fig 2). Fibroleiomyoma contrast enhancement that was equal to that of myometrium also was predictive of a good response, although this result was not statistically significant; the ratio of geometric means was 3.65 (95% CI: 0.09, 141.28; P = .46) (Fig 3).

There were two intracavity pedunculated fibroleiomyomas in our series, and these underwent volume reduction of 100% and 87% (both had high signal intensity on T2-weighted images, low signal intensity on T1-weighted images, and exhibited increased contrast enhancement).

MR angiography was performed in 15 women. Prior to embolization, both uterine arteries could be identified in 13 (87%) women. After embolization, neither uterine artery was seen in 10 of the 13 women. In two of the three remaining patients, one uterine artery was identified after embolization; both women had undergone unilateral embolization (volume reduction of 52% and 6% at 2 months). In the third patient, both arteries were visible on postembolization MR angiograms (volume reduction of 7% at 2 months) despite a technically satisfactory procedure.

a. b.

Figure 6. Sagittal T1-weighted gadolinium-enhanced two-dimensional fast low-angle shot MR images (180/4.8, 75° flip angle, 256 × 106 matrix, 300 × 300-mm field of view, 8-mm-thick sections). **(a)** Before embolization, fibroleiomyoma (arrows) enhancement is equivalent to that of the surrounding myometrium. **(b)** After embolization, the fibroleiomyoma (arrows) is no longer enhancing.

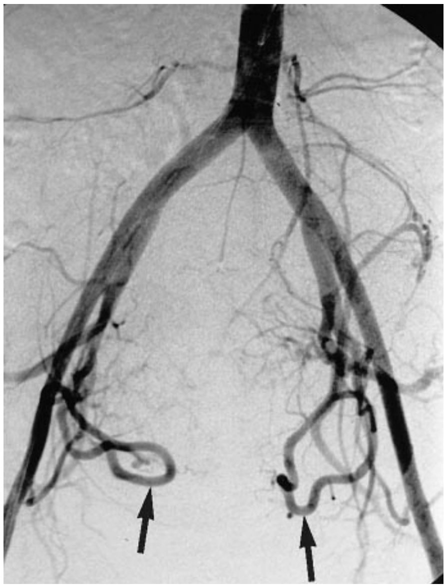


a. b.

Figure 7. Sagittal T2-weighted turbo spin-echo MR images (4,000/99 [effective], 256 × 242 matrix, 220 × 220-mm field of view, 5-mm-thick sections), **(a)** Before embolization, an intracavity pedunculated fibroleiomyoma (arrows) is present. **(b)** After embolization, the fibroleiomyoma is no longer depicted.

DISCUSSION

The mean reduction in fibroleiomyoma volume of 59% in this study was consis-



a.

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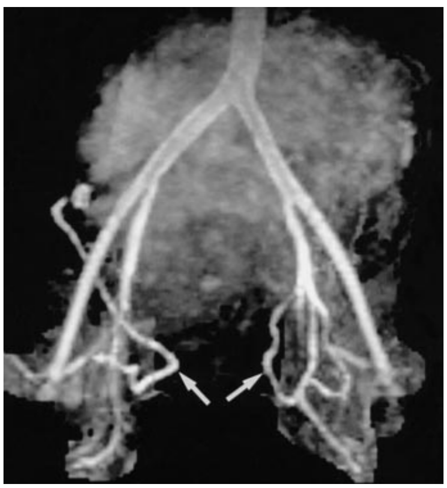

b.

Figure 8. **(a)** Arteriogram and **(b)** corresponding three-dimensional gadolinium-enhanced fast imaging with steady-state precession MR angiogram (6.7/2.8, 30° flip angle, 256 × 140 matrix, 350 × 350-mm field of view, 90-mm slab thickness, 3-mm effective section thickness) obtained before embolization demonstrate both uterine arteries (arrows). **(c)** After embolization, neither artery is present on a gadolinium-enhanced MR angiogram (obtained with same parameters as **b**).

tent with the 40%–70% reductions reported in other series (2–5). The ellipsoid formula for assessing fibroleiomyoma size was convenient to use, and the technique has been shown (6) to be reliable for measurement of uterine volume, as compared with more sophisticated region-of-interest methods.

The effect of initial fibroleiomyoma size on volume reduction was evaluated to test the hypothesis that, on the basis of a simple model of oxygen supply and demand, a large fibroleiomyoma would be more vulnerable to embolization than would multiple small lesions with the same overall volume. The results did not confirm this hypothesis: Both large and small fibroleiomyomas responded to embolization, and the 95% CIs overlapped. Thus, there were no data to indicate that preembolization fibroleiomyoma size was a useful predictor of response.

The increased fibroleiomyoma signal intensity seen on T1-weighted MR images obtained after embolization was thought to result from hemorrhagic necrosis and the presence of blood breakdown products (7). Thus, a fibroleiomyoma that has spontaneously undergone hemorrhagic degeneration because it has outgrown its blood supply would be expected to show a poor volume-reduction response to arterial embolization, which is what we found in our study (Fig 4).

High fibroleiomyoma signal intensity on T2-weighted images was predictive of a good response to embolization (Fig 5). This result confirmed findings in a study by Oguchi et al (8), who found a correlation between signal intensity on T2-weighted images and fibroleiomyoma volume reduction after gonadoliberin (gonadotropin-releasing hormone) agonist therapy. Our findings are due presumably to increased fibroleiomyoma cellularity and/or vascularity, as suggested by the high signal intensity on T2-weighted images, which therefore rendered the fibroleiomyoma susceptible to embolization. We found that the signal intensity on T2-weighted images sometimes was heterogeneous in extent, which reflected the diverse histologic composition of fibroleiomyomas. High signal intensity on T2-weighted images may represent hyaline degeneration, as well as increased cellularity (9). Increased contrast enhancement of a fibroleiomyoma (Fig 6) also is presumably indicative of a lesion with increased vascularity and might be expected to be predictive of a better response; this was not confirmed in our study (the result was not significant).

In clinical terms, high signal intensity on T1-weighted images is useful in that it suggests that embolization is unlikely to be successful. The signal intensity characteristics of fibroleiomyomas on T2-weighted images help predict the degree of volume reduction. More data are needed on the usefulness of gadolinium enhancement.

Both intracavity fibroleiomyomas in our series responded well to embolization. It might be postulated that this was due to the presence in such lesions of a vulnerable arterial supply traversing the narrow peduncle (Fig 7); however, these fibroleiomyomas also had signal intensity characteristics that were predictive of a good result.

Finally, our results suggest that the uterine arteries can, in most cases, be identified prior to embolization and "disappear" after the procedure (Fig 8). MR angiography correctly demonstrated the two cases of unilateral embolization in which one vessel was seen after embolization. It is noteworthy that one patient, whose arteries were visible after the procedure despite bilateral embolization, underwent the second-smallest volume reduction in our series, which represented either unsuccessful embolization or recanalization. Thus MR angiography may have a limited role in assessment of the technical success of embolization by means of evaluation of arterial patency in fibroleiomyomas with unexpectedly poor volume reduction.

It should be emphasized that this was a small study and should be duplicated with a larger series of patients. In summary, we found MR imaging to be useful for assessing volume reduction of fibroleiomyomas after embolization; a high-signal-intensity fibroleiomyoma on T1-weighted images was strongly predictive of a poor response to embolization, whereas high signal intensity on T2-weighted images was predictive of a good response to embolization.

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