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Contribution of contrast-enhanced ultrasound with Sonovue to describe the microvascularization of uterine fibroid tumors before and after uterine artery embolization

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ABSTRACT

Objective: The principal objective of this study was to use contrast-enhanced ultrasonography to describe the characteristics of fibroid microvascularization before and after embolization.
Study design: Forty women had contrast-enhanced ultrasonography with Sonovue® injections before uterine artery embolization, the day afterwards, and at 6–12 months afterwards. An MRI was also performed before and after the procedure.
Results: Two thirds of the fibroids took up the contrast product before the myometrium did, and 45.8% were vascularized along the peripheral rim of the fibroid, compared with 41.6% with a principal pedicle and from the center in three (12.6%). After embolization at day one (D1), the myometrium was fully enhanced, that is, perfusion of the myometrium was plainly visible, in 25 cases (69.4%; $n = 36$), partially enhanced in eight (22.2%), and totally avascular in three (8.4%). Analysis of the failures according to imaging criteria the day after embolization (D1) showed failure in seven women, with partial enhancement for six, and total for one. In the imaging at 6 months (M6), contrast ultrasonography showed failure for three women, with enhancement of the largest fibroid. This enhancement was total in two cases and partial (40%) in one. There were five failures according to MRI at M6, with partial enhancement. Only two of these failures were simultaneously failures according to the contrast-enhanced ultrasonography. There were five clinical failures, two consistent with the imaging at 6 months and four predictable on D1.
Conclusion: Contrast-enhanced ultrasonography is feasible and useful to understand fibroid vascularization and for monitoring embolization; its correlation with MRI is good, its concordance less so.

Introduction

Because of the good clinical results reported (85–90% at 5 years), uterine artery embolization (UAE) has emerged as the principal alternative to surgery [1–7]; UAE represents 40% of the treatment for fibroid in our institution.

Within the fibroid, vascularization is centripetal [8,9], and the central area is the most sensitive to spontaneous ischemic accidents (which explains the necrobiosis of some fibroids). The failure of power Doppler to show fibroid microvascularization adequately presents two persistent limitations for the early assessment of embolization results: difficulties both in the early and inexpensive assessment of radiologic response to treatment and in determining the vascular factors that predict this response.

MRI with gadolinium injection allows a good assessment and is considered a reference method, but it is not always available and remains expensive [1].

Sonography with the peripheral injection of a second-generation ultrasound contrast product (Sonovue®) can now characterize

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tumor vascularization and makes it possible to map its microvessels with precision.

The principal objective of this study was to use contrast-enhanced ultrasonography to describe the characteristics of fibroid microvascularization before and the day after embolization.

The secondary objectives were: to determine the radiologic predictive factors and the concordance of MRI and contrast-enhanced ultrasonography for successful embolization.

Material and methods

This prospective study took place at Tours University Hospital Center from 2008 to 2011. It included 40 women aged at least 18 years with at least one symptomatic uterine fibroid (size between 6 and 9 cm) for which embolization was planned. Approval from our institution's review board and local ethics committee was obtained and written consent signed by the patients.

The exclusion criteria were: intracavitary uterine mass suggestive of submucous fibroid type 0 or 1, polyps or endometrial cancer, fibroids not accessible through the abdominal wall for US (because of size or location), menopause, pregnancy, breastfeeding, and contraindications to contrast product injection (recent cardiac condition or history of severe heart disease).

For the protocol, both MRI with gadolinium injection and contrast-enhanced ultrasonography were scheduled for before the one day procedure.

The day after the procedure (D1), a second contrast-enhanced ultrasound was performed to assess the immediate results of the embolization.

The long-term assessment took place at 6–12 months after the embolization: an MRI with gadolinium injection and a contrast-enhanced ultrasound.

For the technique, embolization was done under Analgesia combining an injection of 2% lidocaine in the inguinal fold and intravenous injection of midazolam. Routine antibiotic prophylaxis by amoxicillin and metronidazole began during surgery and continued for 24 h. Bilateral embolization was performed with particles of increasing sizes made of trisacryl microspheres (500–700 μm, then 700–900 μm, sometimes 900–1200 μm) injected in flow free into the fibroid or as distal to it as possible, until either near-complete arterial stasis in the target area or an arterial pathway to the ovaries was observed. The procedure was completed by temporary proximal embolization of the uterine arteries by rapidly resorbed particles (Spongel®, Curaspon®).

Postoperative pain was managed with the patient-controlled analgesia (PCA) techniques, using morphine, paracetamol and nonsteroidal anti-inflammatory drugs. Women were generally discharged on day 1 exceptionally on day 2 after contrast-enhanced ultrasonography.

The ultrasound examinations were performed using abdominal and transvaginal ultrasound, with power Doppler to assess the morphology and vascularization of the mass.

A Technos MPX (ESAOTE SpA Biosound Genova, Italy) with dedicated CnTI software was used. CnTI is a technique adapted to maximize contrast-to-tissue ratio with minimal tissue generated echoes and minimal electronic noise. This was done using narrow transmission signal and narrow receiver band-width focused on second harmonic for Sonovue®. Harmonic response from tissue differs from that of Sonovue® allowing an improvement in the differentiation between contrast and tissue for a higher contrast to tissue ratio.

Parameters like PRF gain and filter were never changed. A predefined preset was used for power Doppler examinations (Pulse Repetition Frequency of 1000 Hz for color) and for CnTI:

- Power Doppler frequency = 6.3 MHz.
- Derated pressure (DP) = 126 kPa.
- Parameters setting: SCC = 8 and ENH = 3.
- Focus position = under the ovary.
- General gain: 150.

The indicators analyzed were the size of the largest fibroid and the uterus on all three axes, according to the formula: length × width × thickness × 0.523. Power Doppler allowed us to define the presence and type of vascularization: absence of vascularization, peripheral vascularization, central vascularization, substantial mixed peripheral and central vascularization.

The contrast agent used was Sonovue® (Bracco Imaging BV), perfused through a 20 gauge needle into a large vein of the forearm; 2.4 mL was administered as an intravenous bolus as rapidly as possible and then rinsed with 5 mL of saline.

The fibroid plane that showed the best vascularization in power Doppler was scanned and defined the region of interest including the largest possible area of healthy myometrium, to be able to compare their relative perfusion.

The examination then scanned the entire uterus, visualizing all fibroids so that their vascularization and that of the myometrium could both be described. Using contrast ultrasound we could not used more than two Sonovue injections so we choose to look at one main fibroid and full uterus for the myometrium.

All of the images and 5 min videoclips were saved on the ultrasound machine and then on a hard drive.

The indicators analyzed for the pre-embolization, the immediate post-embolization (D1), and the 6–12 month post-embolization examination were: enhancement of perfusion (total, partial or absent), the extent of contrast estimated as a percentage, maximum intensity, time of arrival of contrast product, time to peak, time at peak, time until 50% intensity, slope of the decreasing curve, and area under the curve. All the fibroids were observed for contrast enhancement using ultrasound or gadolinium for MRI, but measurements were done only on the largest.

All quantifications were calculated a considerable time after the examination by the same operator, using the most recent version of the Sonoliver quantification software (Bracco imaging France SAS).

MRI (1.5 tesla magnet) was performed before embolization and from 6 to 12 months afterwards.

Each pre-embolization examination included T2-weighted slices in all three planes. T1-weighted slices were acquired before and after intravenous injection of 0.1 mmol/kg of gadolinium in two of the planes and after fat saturation for the injected sequences in pre- and post-embolization examination to assess the residual vascularization and the reduction in volume of the fibroids.

The indicators analyzed were the same as US: the fibroid signal and enhancement were assessed and compared with those of the myometrium, as hyper-, iso-, or hypo-intense signals.

The operator quantifying the ultrasound and analyzing the MRI was masked to the results of the other technique.

Imaging failure definition was persistent enhancement at D1 for US and/or persistent enhancement at M6 for contrast US and MRI.

The clinical assessment before and after the embolization was based on questioning the patients at both times about bleeding, pain, and pelvic discomfort. It was built to determine if the symptoms had improved.

Bleeding was qualified as normal, heavy, or very heavy, while pain and pelvic discomfort were described as absent, mild or strong. The symptoms as a whole were quantified by a discomfort score, rated as 1, 2, or 3 according to the extent of the symptoms. The maximum score was therefore 9 and the minimum score 0.

Clinical failure was defined as an absence of improvement in either symptoms or the discomfort score at 6 months. The criteria for imaging failure were the persistence of enhancement (perfusion) of the dominant fibroid or the reappearance of a vascularized fibroid at 6 months.

The clinical assessment also considered pain, assessed by two methods:

- A visual analogic scale of 100 mm (VAS), with values collected at T0, the end of the embolization, and then at 2, 4, 6, 8, 10, 12, 24, and 36 h.
- Quantification of the total dose of morphine consumed (PCA of morphine, set up in the recovery room).

For statistical analysis, the first part of the analysis consisted of a descriptive analysis of the different indicators collected during the 2D ultrasound, and then after the Sonovue injection and their univariate analysis (means or medians and standard deviations or interquartile intervals). Correlations were studied with the intraclass correlation coefficient and concordance analyzed with Bland–Altman plots. The Kruskal–Wallis test was used to assess the differences between the medians; differences were considered significant when $p < 0.05$.

Results

The women's mean age was 44 ± 6 years, and their mean BMI 25.2 ± 5.5. All women had hormone therapy, which failed, and two had already had a myomectomy that was followed by the reappearance of symptoms.

Nine vials of particles, on average, were used per patient, all particle sizes combined.

The interviews (history and symptoms) taken before the procedure and then at 6–12 months showed a clear improvement in all symptoms. Of the 40 women studied, five were lost to follow-up and could not be questioned at 6 months. Table 1 describes the symptoms before and after treatment.

The overall discomfort score, rated from 0 to 9, showed improvement for 32 women and no improvement for three. No woman's score had deteriorated; the mean score was 6.4 [5.9–6.8] before the intervention, and 3.6 [3.3–3.9] ($p < 0.0001$) 6–12 months afterwards.

Table 1
Clinical characteristics of women before embolization and at 6 months.

Characteristics	Pre-embolization *n* (%)	M6 *n* (%)
Bleeding	*n* = 39	*n* = 35
Normal	10 (25.6)	30 (85.7)
Heavy	9 (23.1)	2 (5.7)
Very heavy	20 (51.3)	1 (2.9)
Other	0 (0)	2 (5.7)
Pain	*n* = 38	*n* = 35
Absent	13 (34.2)	28 (80)
Mild	10 (26.3)	6 (17.1)
Strong	15 (39.5)	1 (2.9)
Pelvic discomfort	*n* = 39	*n* = 35
Absent	11 (28.2)	26 (74.3)
Mild	14 (35.9)	7 (20)
Strong	14 (35.9)	2 (5.7)

Flow chart of participation was presented in Fig. 1.

The seven missing MRI were due to non-recorded sequences or claustrophobic patients.

Using MRI, mean uterine volume reduction was of 44% and of 67% for the largest fibroid, one fibroid had disappeared completely in a woman.

Table 2 describes fibroid vascularization before and after embolization.

Using US, mean uterine volume reduction was of 46% and of 69% for the largest fibroid, one of the other two women had transvaginal ultrasound because of the fibroid size reduction. The mean number of fibroids was stable at two, although one woman no longer had any.

Before embolization, rich internal and peripheral vascularization was seen in 44.7% of the fibroids, while at 6 months, 90% showed no vascularization at the power Doppler examination (Table 3). Before embolization, Doppler was not able to detect vascularization in two cases. It was the same for MRI, using contrast these women had partial enhancement.

In terms of time to enhancement, fibroids were enhanced before the myometrium in 16 patients (66%; $n = 24$), after the myometrium in two (8.3%) and simultaneously in six (25%).

The fibroid uptake was centripetal from the peripheral rim in 11 cases (45.8%), branching in 10 cases (41.6%), and from the center in three (12.6%).

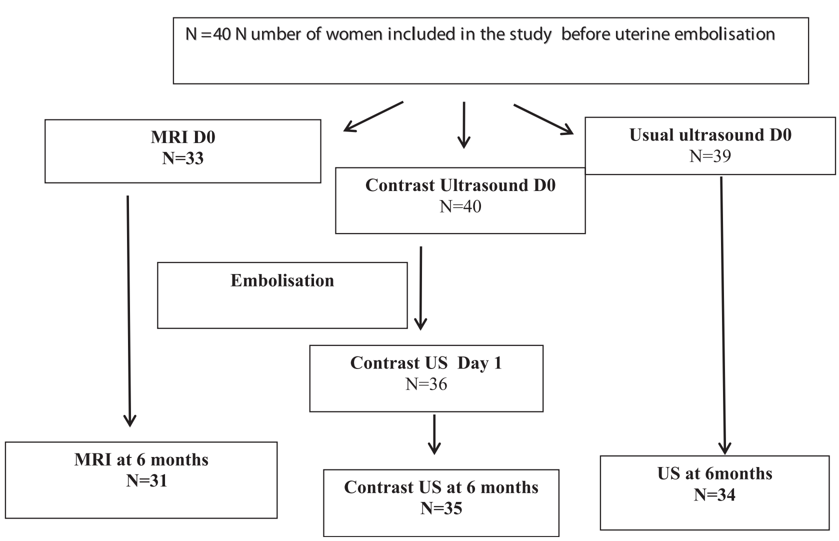

Fig. 1. Flow chart of the study: 40 women included at the beginning.

Table 2
MRI characteristics before embolization and at 6 months.

Characteristics	Pre-embolization	M6
Uterine volume uterus (cm^3), med [IQI], $n = 31/32$	351 [213; 576]	197 [95; 277]
Volume of largest fibroid (cm^3), med [IQI], $n = 33/30$	126 [46; 354]	54 [19; 146]
Number of fibroids, med [IQI], $n = 34/30$	3 [1; 5]	3 [1; 4]
Enhancement perfusion (%)	$n = 30$	$n = 33$
Absent	2 (6.7)	28 (84.8)
Partial	4 (13.3)	5 (15.2)
Total	24 (80)	0 (0)
T1-weighted signal (%)	$n = 29$	$n = 8$
Hyper	2 (6.9)	2 (25)
Iso	26 (89.7)	4 (50)
Hypo	1 (3.5)	2 (25)
T2-weighted signal (%)	$n = 30$	$n = 16$
Hyper	12 (40)	1 (6.3)
Iso	0 (0)	2 (12.5)
Hypo	18 (60)	13 (81.2)

Table 3
Ultrasound characteristics before embolization and at 6 Months.

Characteristics	Pre-embolization	M6
Uterine volume uterus (cm^3), med [IQI], $n = 40/27$	311 [167; 613]	162 [102; 270]
Volume of largest fibroid (cm^3), med [IQI], $n = 36/24$	152 [67; 341]	47 [20; 159]
Number of fibroids, med [IQI], $n = 38/32$	2 [1; 3]	2 [1; 3]
Echogenicity, n (%)	$n = 38$	$n = 28$
Homogeneous	13 (34.2)	8 (28.6)
Heterogeneous	25 (65.8)	18 (64.3)
Lacunae	0 (0)	2 (7.1)
Doppler score (%)	$n = 38$	$n = 30$
No vascularization	2 (5.3)	27 (90)
Vascularization around Rim	19 (50)	1 (3.3)
Central vascularization only	0 (0)	1 (3.3)
Substantial vascularization around rim and central	17 (44.7)	1 (3.3)

Quantitatively, pre-embolization ($n = 40$) enhancement of the fibroid was total in 33 cases and partial in seven. The myometrium was always completely enhanced (Fig. 2).

Table 4 compares these indicators for the larger fibroids with those for the myometrium.

At the early post-embolization examination, the myometrium and the fibroids enhancements were described in Table 5.

At 6 months, embolization of five patients appeared to have resulted in clinical failure, defined by a discomfort score identical to that before embolization. Contrast ultrasonography showed failure for three women, with enhancement of the largest fibroid: total in two cases and partial (40%) in one Fig. 3. Only one of these three women had had persistent enhancement at D1. Besides these three, embolization was considered a failure from the imaging perspective for two other women who had new or persistent vascularized small fibroids.

MRI at 6 months also showed enhancement of the largest fibroid in five women, two also considered clinical failures.

The study of pain showed a median morphine dose (PCA) of 20 mg/d (12; 30.5). No correlation was found between the total

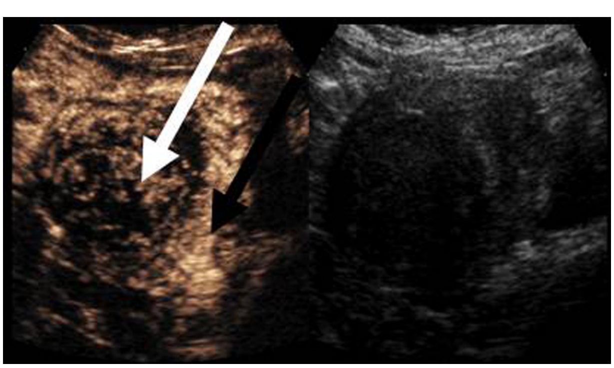

Fig. 2. Ultrasound of uterus before embolization after contrast enhancement showing the hyper enhanced myometrium (black arrow) and the less enhanced fibroid (white arrow).

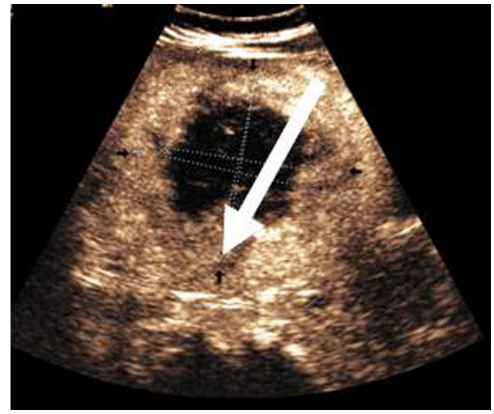

Fig. 3. Ultrasound of a fibroid at M6 after contrast enhancement showing partial necrosis with persistent vascularized zone (white arrow).

Table 4
Quantitative analysis of contrast-enhanced ultrasonography of the fibroid and the myometrium.

Characteristics	Fibroid	Myometrium
Quantification, med[IIQ]	0.22 [0.17; 0.33]	-
Peak max contrast, med [IIQ]	1024 [412; 1930]	1172 [211; 1908]
T arrival CP [mean ± and se]	15.1 ± 2.8	16.5 ± 3.0
T rise to peak [mean ± and se]	18.8 ± 6.1	22 ± 8.3
T at peak [mean ± and se]	33.3 ± 8.1	36 ± 9.9
T at 50% (s), med [IIQ]	44.6 [32.9; 50.4]	45.4 [38.1; 67.4]
Slope, med [IIQ]	29.2 [17.2; 52.9]	19.7 [5.3; 56.9]
AUC, med[IIQ]	29710 [8413; 81620]	33820 [11890; 88550]

Table 5
Quantitative analysis of contrast-enhanced ultrasonography for principal fibroid and for myometrium, before, immediately after, and 6 months after embolization.

Characteristics	Pre-embolization	Post-embolization	M6
Fibroid			
Enhancement perfusion (%)	$n = 40$	$n = 39$	$n = 35$
Absent	0 (0)	32 (82)	32 (91.4)
Partial	7 (17.5)	6 (15.4)	3 (8.6)
Total	33 (82.5)	1 (2.6)	0 (0)
Echogenicity, n (%)		$n = 39$	
Homogeneous	–	2 (5.1)	–
Heterogeneous	–	31 (79.5)	–
Lacunae	–	6 (15.4)	–
Myometrium			
Enhancement perfusion (%)	$n = 40$	$n = 36$	$n = 35$
Absent	0 (0)	3 (8.4)	0 (0)
Partial	0 (0)	8 (22.2)	0 (0)
Total	40 (100)	25 (69.4)	35 (100)

morphine dose and characteristics of either the women or the embolizations (Table 6).

Similarly, no correlation was demonstrated for pain with the characteristics of myometrial enhancement in contrast mode at D1 $\rho = 0.11$.

The analysis of the correlations and concordances for uterine volume, volume of the largest fibroid and for the number of fibroids between conventional ultrasound and MRI, is presented in Table 7. Concordances as analyzed by Bland–Altman plots, was poor, especially for the larger volumes. (Funnel aspect on plots). *(Figs. 4, 5, and 6 present the analysis of the concordance.)* The trend shows underestimation of uterine and fibroid volumes and fibroid number by ultrasound. The analysis of the correlations with the quantitative variables in contrast mode shows no correlation, whether for the reduction in size of the largest fibroid or for the heterogeneity of the fibroid.

Only the analysis of the largest fibroid shows a very nearly but insignificant correlation with time to contrast product arrival and significant correlations with both time of peak and time to 50% intensity; there was no correlation with either rPA or with maximum intensity.

The analysis of the concordance between MRI and contrast-enhanced ultrasonography shows that of the five women with a fibroid partially enhanced on MRI, two were also partially enhanced in contrast mode, while three were considered to show no enhancement (Table 8). The third with a partial enhancement on contrast-enhanced ultrasonography did not have an MRI at 6 months. Five women had a clinical failure; using contrast, four of them had at D1 a partial enhancement of the fibroid, suggesting that enhancement at this time is predictable of clinical failure later on. Overall, only one clinical failure was not predictable by contrast ultrasound at D1 and was not correlated with imaging at M6.

Comment

First reported in 1995 in France [3], uterine artery embolization for the treatment of fibroids has developed slowly in Europe improved by the guidelines recently published [1].

Contrast-enhanced ultrasound based on vascular exploration appeared to us to be a promising technique for assessing the probability of success for fibroid treatment and determining its predictive factors.

Our study made it possible to describe the microvascularization of fibroids and the vascular kinetics of fibroids within the myometrium. Two thirds of the fibroids took up the contrast product before the myometrium and 45% were vascularized peripherally, around the edges, compared with 41% that had a principal pedicle. These findings help us to understand how fibroids can be embolized without embolization of the myometrium, as happens in 90% of the cases. It is difficult sometimes to see vascularization in the middle of the fibroid, that's why 50% of the fibroids had only rim vascularization using Doppler. Before treatment contrast or gadolinium were more useful and precise for vascularizations location and quantification with 82.5% and 80% of detection respectively.

We did not, however, find any quantitative vascular indicator or characteristic that served to predict the result, either immediately after the procedure, or months later. Nor did perceived pain during hospitalization help to predict outcome. Contrast-enhanced ultrasonography nonetheless allows sometimes an early evaluation of the embolization by visualizing either partial or no enhancement—that is, only partial or no vascular perfusion on D1 was evidence of probable clinical failure in the intermediate term (4/5 patients). Contrast US is also successful later on at M6 but not always correlated to clinical failure (Fig. 2). Using contrast US, if scanning the uterus and all the fibroids to detect absence of vascularization is easily done, one limit is that it is not possible to do it for each fibroid when there is several of them, because one Sonovue injection is necessary for each measurement, and doing more than two injections is not allowed.

Despite a relatively low number (40 patients), these results are quite similar to those of other studies conducted to assess different methods of imaging or their feasibility [10–13].

To our knowledge, this is the first study to have used contrast-enhanced ultrasonography to study immediate response to embolization. Zhou et al. [14] also assessed ultrasound with Sonovue injection, but at 1 week after the high-intensity focused ultrasound ablation, by assessing the residual tumor rate.

In our study, immediately after embolization, fibroid enhancement was absent in 82.5% and partial or total in 17.5%, while myometrium was totally enhanced in 70%, due to reperfusion by collateral vessels and to the size of the myometrial vessels.

De Souza et al. [12] looked at early changes in perfusion on MRI show the same results in relation to clinical outcome.

Although results of these two studies are consistent in terms of vascularization changes, they remain limited by the low number of patients (11 and 40).

Using contrast parameters we could not show any correlation between response and hypervascularization of the fibroids, nor find new factors that predicted response to treatment [10–19].

Table 6
Correlation coefficient between pain and characteristics of the woman and the embolization.

	ρ	95% CI
Initial uterine volume	0.09	[−0.27; 0.43]
Initial volume largest fibroid	0.05	[−0.30; 0.38]
Variation uterine volume	0.19	[−0.22; 0.55]
Variation fibroid volume	0.11	[−0.31; 0.49]
Number fibroids	0.02	[−0.33; 0.35]
Number vials used	0.13	[−0.21; 0.45]
Peak max contrast fibroid	−0.16	[−0.53; 0.26]

Table 7
The analysis of the correlations and concordances between conventional ultrasound and MRI for uterine volume, volume of the fibroid and number of the fibroids.

Studied parameter	Intraclass correlation coefficient	Concordance with the confidence intervals of the limits of agreement	Systematic bias in favor of MRI
Uterine volume D1	0.83 [0.68–0.91]	[−367; 264]	−51
Uterine volume M6	0.80 [0.59–0.90]	[−210; 170]	−20
Fibroid volume D1	0.93 [0.86–0.96])	[−166; 113]	−26
Fibroid volume M6	0.84 [0.66–0.92]	[−128; 59])	−34
Fibroid number D1	0.66 [0.42–0.81]	[−4.3; 2.7])	−0.8
Fibroid number M6	0.70 [0.44–0.84]	[−3.9; 2.3]	−0.8

Table 8
Concordance between clinical failure after fibroid embolization and contrast US and MRI after 6 months.

Patient	Clinical failure	Contrast US M6	MRI M6
P2	+	-	+
P6	+	+	+
P21	+	-	-
P29	+	-	-
P14	+	?	?
P35	-	+ (NF)	-
P4	-	+ (NF)	-
P22	-	+	+
P33	-	+	?
P27	-	-	+
P37	-	-	+

(+) = failure. (NF)= New fibroid. ? are unknown result.

These results are consistent with others obtained using 3D Doppler ultrasound [10] or MRI [13,17]. De Souza et al. [12] found like us that although vascularization did not predict good response, clinical response was correlated with the extent of reduction in perfusion after embolization, while they attributed the good volume response to T2-weighted hyperintensity.

At pre-embolization, when total enhancement (hyperintense signals) is seen, there was a perfect concordance in the perfusion observed in MRI and contrast-enhanced ultrasonography. This concordance is not observed at 6 months when the enhancement is only partial. Pelage et al. [20] comparing two MRI readers, showed excellent concordance for totally avascular or totally perfused fibroids. This concordance was reduced when the enhancement or perfusion is intermediate.

Although the percentages of variation of volume seem relatively similar between MRI and conventional ultrasound

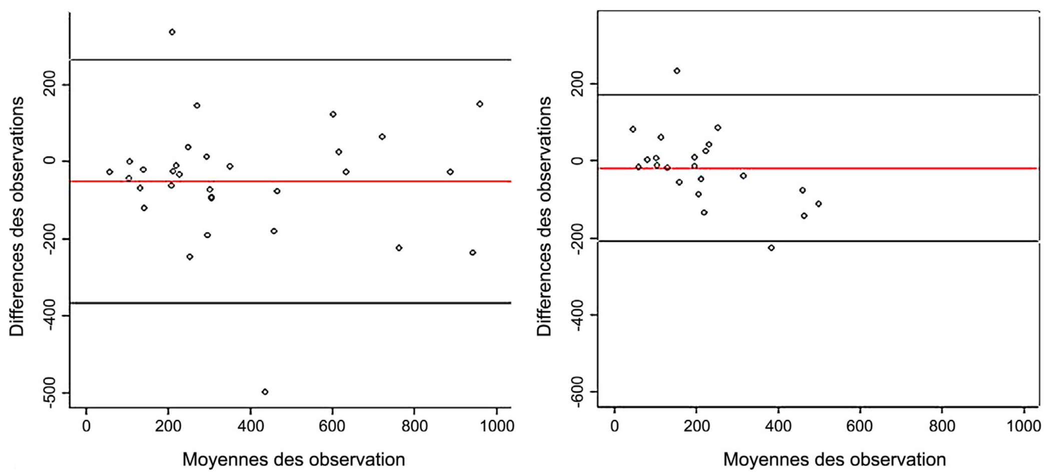

Fig. 4. A and B: Analysis of the concordance between ultrasound and MRI for uterine volume before embolization (left A) and 6 months after embolization (right B). The X axis presents the means of the values obtained on MRI and ultrasound. The Y axis presents the difference between the values calculated for each imaging mode.

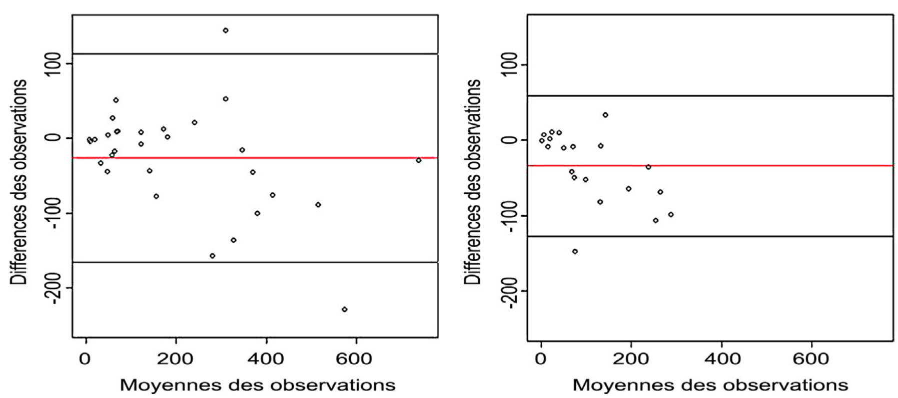

Fig. 5. A and B: Analysis of the concordance between ultrasound and MRI for the volume of the largest fibroid before embolization (left A) and 6 months after embolization (right B). The X axis presents the means of the values obtained on MRI and ultrasound. The Y axis presents the difference between the values calculated for each imaging mode.

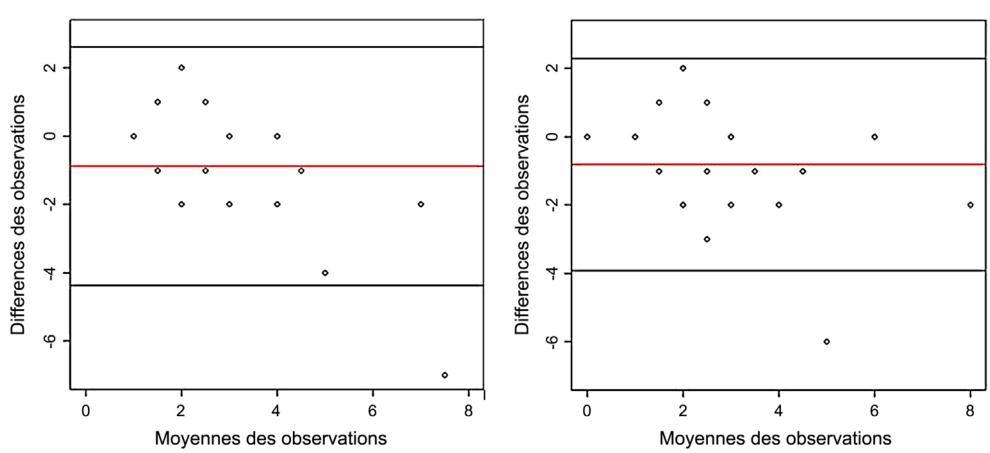

Fig. 6. A and B: Analysis of the concordance between ultrasound and MRI for the number of fibroids before embolization (left A) and 6 months after embolization (right B). The X axis presents the means of the values obtained on MRI and ultrasound. The Y axis presents the difference between the values calculated for each imaging mode.

[21], the analysis of concordance in our study found weak concordance between these two imaging methods, with a trend towards underestimation by ultrasound. In 2002, Walker et al. [22] reported a strong correlation between MRI and ultrasound for assessing fibroid and uterine volumes. The analysis of correlation seems to us insufficient: when we focused on the intraclass coefficient in our study, we found a strong correlation, while concordance, as analyzed by Bland–Altman plots, was poor, especially for the larger volumes. (Funnel aspect on plots). Figs. 4–6.

Others [23,24] found that the disparity of MRI compared with ultrasound increased with uterine volume.

Like in our study, no correlation has been shown [24–27] between pain and embolization, technique, or size or type of embolization material, or with size, site, or number of fibroids. Only Volkers [25] in his analysis of 81 patients found higher pain scores related to the quantity of particles used.

Contrast-enhanced ultrasonography, an inexpensive method, permits a good analysis of enhancement and perfusion and allows intraoperative and immediately postoperative verifications [28,29]. Moreover; it is not less valuable than MRI for the assessment at 6 months.

A sequence of pre-operative MRI and contrast-enhanced ultrasonography for immediate and 6-month verifications check-ups seems possible. Indeed, it has not been shown that outside of research studies such as this one, routine follow-up monitoring using imaging is useful in the absence of clinical failure. At most, imaging failure can only be a risk factor for clinical failure.

Conflict of interest

There is no conflict of interest with Bracco as Pr Tranquart was not working for Bracco at the time of the study, and our study was financed completely by public funds.

Condensation

Contrast-enhanced ultrasound is feasible and useful to understand fibroid vascularization and for monitoring embolization; its correlation with MRI is good, its concordance less so.

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