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UTERINE ARTERY EMBOLIZATION FOR UTERINE FIBROIDS: PREDICTIVE MRI FEATURES OF VOLUMETRIC RESPONSE

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Summary

The aim of this study was to investigate whether initial fibroid volume, FIGO classification, signal intensity ratio (SIR) on T2-weighted magnetic resonance images (MRI) and the number of fibroids affect the outcome of Uterine Artery Embolization (UAE) as well as report of 6-year single-center experience with UAE procedures. Medical history, UAE and MRI examinations from 75 patients from the Sestre milosrdnice University Hospital Centre who underwent UAE between 2017 and 2023 were reviewed retrospectively. Results showed a negative correlation between baseline fibroid volume and volume reduction of the fibroid, with larger fibroids showing smaller volume reduction ($p < 0.001$). There was a statistically significant difference between FIGO classification groups and volume reduction of the fibroids. Submucosal fibroids showed the best volume reduction compared to hybrid fibroids and subserosal fibroids. There was no significant difference between hybrid and subserosal fibroids in volume reduction. We found no correlation between MRI SIR and the number of fibroids on UAE procedure outcomes. The present study suggests that submucosal fibroids and smaller baseline fibroid volume could be related to greater volume reduction and may be a useful prognostic factor for UAE procedure success. In conclusion, this study confirms that UAE is a safe and effective procedure for the treatment of uterine fibroids.

KEYWORDS: *magnetic resonance imaging (MRI); uterine artery embolization (UAE); uterine fibroid*

INTRODUCTION

Uterine fibroids, otherwise known as leiomyomas or myomas are benign monoclonal tumors that arise from the myometrium smooth muscle cells and have a large extracellular matrix(1). Their prevalence is reported to be around 70% to 80% in women who have reached the age of 50, therefore being one of the most common gynecological tumors(2). Cramer et al. reported a fibroid prevalence of 77% in post hysterectomy study(3).

Fibroids may be asymptomatic and are often found incidentally through regular clinical examinations or imaging. However, they can cause significant symptoms such as heavy and prolonged menstrual bleeding and bleeding between periods, which often results with anemia(4). Depending on location, type and size of the fibroid many women report bulk symptoms, which include urinary bladder pressure, back, leg, and pelvic pain, pelvic pressure, frequent urination, incontinence, or constipation(5).

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There are various treatment options for fibroids, including expectant management, pharmacological therapy and surgical procedures. More recently some minimally invasive procedures like uterine artery embolization, percutaneous thermal ablation and high-intensity focused ultrasound have shown promising results allowing the preservation of the uterus. Surgical options can vary from laparotomy or laparoscopic myomectomy, which is considered the golden standard procedure for the treatment of this condition, or as a last option, surgical hysterectomy(6). The decision for treatment option is based on clinical symptoms, age connected with reproductive status of the patient, location, number and size of the uterine fibroids(7).

UAE was first described in 1995 by Ravina et al. as a treatment for uterine fibroids. They showed it as a safe and effective treatment option resulting in 20-80% fibroid volume reduction(8). The procedure has been validated as a safe, cost-effective and efficacious treatment option with shorter hospital stay, lower incidence of serious complications and a faster return to normal activity when compared to myomectomy and hysterectomy. Long term postprocedural results show similar clinical improvement when compared to myomectomy(9). According to current Society of Obstetricians and Gynecologists guidelines, UAE should be offered to selected women with symptomatic fibroids, who want to preserve their uterus but are not planning pregnancy because fecundity and pregnancy may be impacted by the procedure(6).

Various predictive MRI features have been researched to try to predict the volumetric response of the fibroids following UAE. One of the most studied predictive factors is the location of the fibroid, which is categorized by fibroid FIGO classification(10). Submucosal locations have been shown to have a better volumetric response when compared to non-submucosal locations(11). Other possible predictive factors are signal intensity ratio on T2-weighted (T2W) magnetic resonance images (MRI), baseline preprocedural fibroid and uterine volume, initial number of fibroids, age of the patient and others. High intensity on T2W MRI has been shown to be good predictive factor for volumetric response when compared to hypointense fibroids(12). T2W-hyperintense fibroids are made of compact, smooth muscle cells and have increased vascularity, therefore, theoretically, they should have a better response to UAE. Previous studies have correlated the signal intensity ratio (SIR) of the signal intensity of, usually, iliopsoas muscle, and the signal intensity of the fibroid. The higher the SIR between the muscle and the fibroid on T2W imaging, the better fibroid volume reduction was observed(13).

The objective of this study was to collect data from a single center cohort of patients who have undergone uterine artery embolization (UAE). The analysis aimed to evaluate imaging volumetric measures, clinical outcomes and assess the efficacy of this method. Additionally, we tried to evaluate whether there is a correlation between fibroid volumetric reduction rate and location of the fibroids according to FIGO classification, signal intensity ratio on T2-weighted imagery, the initial volume of the fibroid and the initial number of fibroids in the uterus.

METHODS

We retrospectively reviewed all patients who had UAE at our institution between January 2017 and November 2023. A total of 75 women with symptomatic uterine fibroids were referred to our Department of Diagnostic and Interventional Radiology for a UAE. These patients were initially referred to gynecologists primarily due to symptomatic fibroids and were presented with UAE as an alternative to other therapeutic options. The final decision was multidisciplinary made by the gynecologist, interventional radiologist and the patient, considering the patient's age, symptoms and desire for uterus preservation. Each patient received a comprehensive assessment by an interventional radiologist specialized in UAE. Preprocedural MRI was conducted to confirm the fibroid diagnosis and assess both the extent of the disease and the vasculature associated with the fibroids.

Patients leading symptoms were collected from gynecological reports. Inclusion criteria were symptomatic patients with a confirmed presence of one or more fibroids on MRI. Patients with suspicious malignancy findings on MRI or ultrasound imaging, as well as those who had repeated two or more UAE procedures, were excluded.

According to the Society of Interventional Radiology (SIR), the complications of the procedure were divided into minor and major complications. Minor complications were defined as those with

no consequences for patients and the patients received no therapy or were admitted for overnight observation. An example of a minor complication is prolonged pelvic pain with increased inflammatory parameters. Pelvic pain and discomfort, which can be accompanied with nausea, low-grade fever, leukocytosis, rise in C-reactive protein after the procedure that requires analgesic treatment is known as postembolization syndrome(14). Postembolization syndrome was not defined as a complication since it is expected in the majority of patients. Major complications were defined as those when the patient required major therapy, prolonged hospitalization longer than 48 hours, permanent adverse sequelae, or death(15).

MRI protocol

All patients underwent a preprocedural and 6 months later postprocedural MRI of the pelvis. Axial and sagittal fast-spin echo T2WI, sagittal T1WI with fat saturation, diffusion-weighted imaging, and contrast-enhanced T1-weighted imaging were performed. Contrast enhanced MRI was performed 2 minutes after intravenous injection of 10 mL gadolinium-based contrast agent.

Image analysis

All MRI images were analyzed by experienced radiologists with a digital workstation that allows interactive image analysis. Uterine fibroids were assessed on the T2-weighted and post-contrast MRI images and the uterus and fibroids were measured in three dimensions. The largest uterine fibroid was noted as a dominant fibroid and was classified according to the FIGO classification of fibroids(10). Submucosal fibroids were labeled as group A, hybrid fibroids were labeled as group B, and subserosal fibroids were labeled as group C for easier data presentation in fibroid location analysis. The volumes of the uterus and dominant fibroid were calculated using a prolate ellipse volume formula (length x width x depth x 0.523)(16). The reduction in uterine and fibroid volume was calculated and expressed as a percentage as follows: 100 x ([volume before UAE – volume after UAE] / volume before UAE).

A follow-up MRI was performed in all patients 6 months after the procedure. Contrast-enhanced T1-weighted images were acquired as well, and the lack of fibroid contrast imbibition was classified as complete infarction of the fibroid, partial imbibition with the contrast was classified as partial infarction and lack of postcontrast imbibition was classified as no infarction of the dominant fibroid. If the dominant fibroid was no longer seen at postprocedural MRI, it was marked as infarcted and expulsed from the uterus.

T2 signal intensity (SI) of the dominant fibroid was measured using a circular region of interest (ROI), matching the size of the dominant fibroid. SI of the iliac muscle on either side was measured using the same approach and tended to have a minimum size of about 100mm^2 when placed in the central part of the muscle. The SI fibroid-to-iliac muscle ratio was calculated as SI of the dominant fibroid/SI of the iliac muscle on the T2W image.

UAE procedure

In all cases, UAE was performed with the patient under mild sedation and local anesthesia via left brachial or radial artery access. A 4F vertebral catheter was placed in the internal iliac artery and advanced into the uterine artery. Prior to the uterine artery embolization all patients underwent uterine angiography to visualize the fibroid opacification and evaluation of possible utero-ovarian anastomoses. Perifibroidal plexus vessels are generally 500-800 μm in caliber, which was the basis for the selection of embolization particles(17). Embolization was performed with Embosphere® microspheres 500-700 μm and 700-900 μm in size or with Hydropearl® 600 μm and 800 μm particles. Embolization was performed until stasis of blood flow was achieved in the uterine artery without visible fibroid contrast uptake (Figure 1). The postembolization syndrome was managed with nonsteroidal analgesics, anti-emetics and opioid analgesics when necessary(18).

Statistical methods

Wilcoxon signed-rank test was used to see whether there was statistical difference between preprocedural and postprocedural uterine and fibroid volumes. Spearman's rank correlation was used to assess the relationship between initial fibroid volume, signal intensity ratio on T2W imaging, number of fibroids, and the volumetric reduction rate. The statistical relationship between FIGO classification and volume reduction was sta-

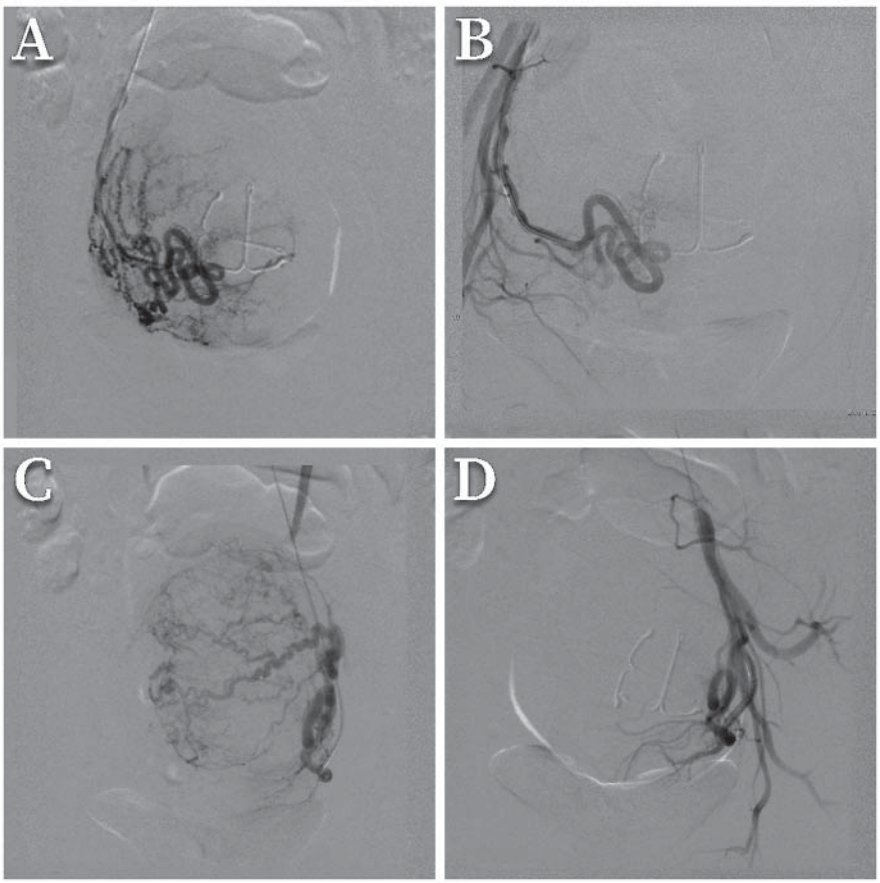

*Figure 1. Digital subtraction angiography during uterine artery embolization of the same patient. Using a transbrachial approach, preprocedural angiography visualized the left and right uterine artery branching out and feeding the large fibroid (***A, C***). After superselective catheterization of both arteries, embolization was performed with 500-700 μm embolization particles until contrast stasis occurred in uterine arteries on repeated angiographies (***B, D***).*

tistically analyzed using the Kruskal-Wallis test. Dunn's pairwise test was carried out for the analysis between the three pairs of groups. The Kruskal-Wallis test was also used to analyze if there were any differences between the fibroid infarction groups. Statistical analysis was performed using IBM SPSS Statistics 26 (SPSS 26; SPSS, Inc., Chicago, IL). A p-value of <0.05 was considered statistically significant.

RESULTS

Out of a total 75 patients, 8 underwent a repeated UAE procedure within the span of one year due to the initial embolization being partialy successfull. Those 8 records were excluded from the study as a previous embolization procedure might affect results, such as the intensity of fibroids and their response to embolization. Additionally, one patient was excluded due to having an hysterectomy in follow-up period due to abscess formation. The rest of 66 patients (mean age 42 ± 6,17 years) met the inclusion criteria. The demographic and clinical characteristics of the cohort population are reported in Table 1. The most prevalent symptom was heavy bleeding, occurring in 71% of the patients, 47 in total. Other symptoms included anemia (29%), menstrual pain (26%), and bulk symptoms (23%). One patient was presented with hypovolemic shock due to heavy and prolonged bleeding from the fibroid and was resuscitated before undergoing the procedure. A total of six patients (9%) reported no symptoms at all at the time of examination but have shown signs of active fibroid growth. Postprocedural MRI was acquired in an average of 7.9 (±1.83) months after the preprocedural MRI.

The median number of fibroids was 3, with 20 (30%) patients having solitary fibroids, while the remaining 46 (70%) patients had multiple fibroids. The most prevalent type of fibroid was hy-

Table 1.

Patient demographics, clinical characteristics, and initial MRI findings.

Age (mean, SD)	41 ± 6.17 years
Symptoms	
Heavy bleeding	47 (71%)
Anemia	19 (29%)
Menstrual pain	17 (26%)
Bulk symptoms	15 (23%)
Hypovolemic shock	1 (2%)
No symptoms	6 (9%)
Median number of fibroids (IQR)	3 (1 – 7)
Number of fibroids	
Solitary	20 (30%)
Multiple	46 (70%)
Location of the fibroids (FIGO)	
Submucosal (FIGO 1,2)	12 (18%)
Intramural (FIGO 3,4)	0 (0%)
Subserosal (FIGO 5,6)	12 (18%)
Hybrid (FIGO 2-5)	41 (62%)
Cervical	1 (2%)
Prior pregnancies	
0	20 (50%)
1	7 (18%)
2	13 (33%)
Miscarriages	
0	25 (81%)
1	4 (13%)
2	1 (3%)
3	1 (3%)

brid (FIGO 2-5), largely attributed by their volume. The median uterus volume before embolization was 448,68 cm^3 which reduced to a median volume of 247,46 cm^3 after embolization. This is equivalent to a median of 37,51% uterine volume reduction. The median dominant fibroid volume before embolization was 96,64 cm^3 which reduced to a median volume of 41,45 cm^3 after embolization (Figure 2). This is equivalent to a median of 55,95% fibroid volume reduction (Figure 3). Results for the whole cohort are summarized in Table 2. Differences between preprocedural and postprocedural uterine and fibroid volumes were found statistically significant (p<0,001).

Five patients (7%) had minor complications, with two patients reporting prolonged lower abdominal pain and cramps seven days after the procedure. Two patients had prolonged vaginal bleeding after the procedure, one reported that it lasted two months after the procedure, and one which resolved itself within a week after the procedure. One patient had a more severe form of postembolization syndrome with high temperature and severe pain in the abdomen which required prolonged analgetic and antipyretic treatment. We report two (3%) major complications. One patient had a generalized grand-mal seizure within 12 hours of the procedure and a neurologist was consulted. It is presumed that seizures were caused by a neurological reaction to intravenous contrast as there were certain indications that she had similar reaction during the prior imaging. The same patient also had heavy vaginal bleeding three weeks after the procedure. The other patient was admitted due to chronic, three month long abdominal pain, which got worse after 3 months and computed tomography showed a necrotic fibroid mass and formation of abscess. The patient was treated with hysterectomy and partial resection of involved small intestines.

Baseline dominant fibroid volume

We assessed whether there were any correlations between the initial dominant fibroid volume and its volumetric reduction in percentage by using Spearman's rank correlation analysis. Significant negative correlation was found between the initial dominant fibroid volume and the volumetric reduction rate on the follow-up imaging (Spearman's r = -.365, p-value = .001). A scatter plot diagram for the correlation is seen in Figure 4.

Fibroid location – analysis

A total of 65 fibroids were compared to see whether there was any difference between the volumetric response and FIGO classification of the dominant fibroid. One patient was excluded from this analysis due to having a cervical fibroid, which could not be compared because of a small sample size. Most of the patients had hybrid fibroids according to the FIGO classification (41 lesions, 63%). The rest of the fibroids were submucosal (18%) or subserosal (18%) in location. The fibroid volume reduction was compared to the

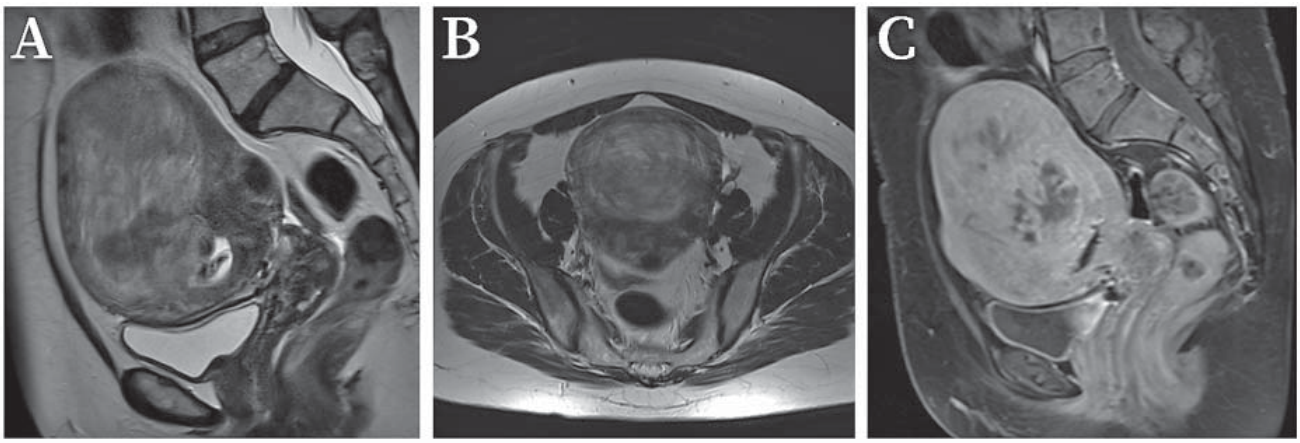

*Figure 2. Preprocedural MRI of a 45-year-old woman complaining of irregular menstrual cycle. Sagittal and axial T2-weighted MR image (**A, B**) showing a large submucosal fibroid that is ≥ 50% intramural (FIGO classification 2) of volume 259 cm³. Sagittal post-contrast T1-weighted image with fat saturation (**C**) showing typical contrast opacification of the fibroid.*

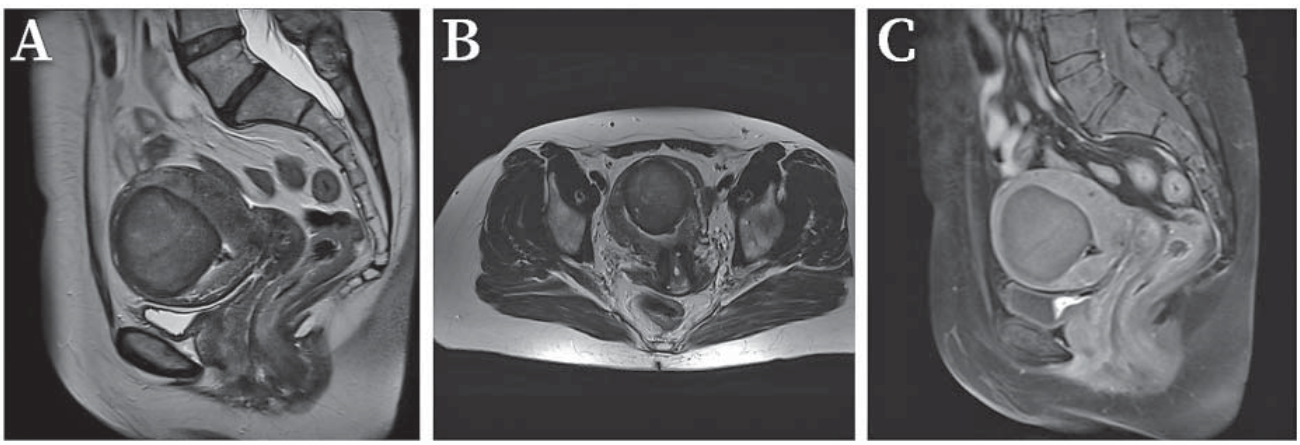

*Figure 3. Postprocedural MRI of the same patient. Sagittal and axial T2-weighted MR image (**A, B**) showing a volume reduction of the fibroid after the procedure, which measures now 69 cm³, accounting for 73,36% volume reduction. Sagittal post-contrast T1-weighted MR image with fat saturation (**C**) showing characteristic loss of contrast opacification showing complete fibroid necrosis and marking the procedure successful.*

FIGO classification of the fibroids, with results presented in **Table 3.** Submucosal fibroids had the best volumetric response to embolization with a median of 80,08% (IQR 53,62 – 92,55). Hybrid fibroids had significantly smaller volumetric reduction with a median of 54,53% (IQR 23,78 – 71,46), compared to submucosal fibroids (p = .014). Subserosal fibroids demonstrated significantly smaller volumetric reduction with a median of 49,29% (IQR 32,66 – 63,02) compared to submucosal fibroids (p = .022). Differences between the volume reduction of the hybrid and subserosal groups were not found to be statistically significant. The boxplot showing this difference between locations can be seen in Figure 5.

Dominant fibroid infarction analysis

Complete dominant fibroid infarction occurred in a total of 49 patients (74%). Out of those 49 patients, three of them probably had an expulsion of the dominant fibroid, as the dominant fibroid was no longer visualized on the follow-up imaging. Partial infarction was seen in 12 (18%) of patients. No infarction occurred in 5 patients (8%). The Kruskal-Wallis test was used to analyze if

there were any differences in initial dominant fibroid volume, signal intensity ratio, and number of fibroids between the groups of dominant fibroid infarction. No statistical significance was found between the variables (p = 0.083). A chi-squared test was used to assess whether the location of the dominant fibroid was correlated with infraction results which showed there were no statistically significant relationship (χ^2 **(4, N = 65)** = 4.902, p = .298). A summary is shown in Table 4.

Signal intensity ratio – analysis

We assessed whether there were any correlations between the preprocedural signal intensity ratio between the dominant fibroid and skeletal muscle on T2-weighted MR imaging and its volumetric reduction in percentage by using Spearman's rank correlation analysis. The median T2 signal intensity ratio was 2,15. Only one fibroid was hypointense on T2 MRI and the rest were hyperintense. There was a small positive correlation where with the increase of SIR on T2W the volume reduction was better, but no statistical significance was found (r_s = .071, p-value = .288).

Solitary vs multiple – analysis

The median volume for a solitary fibroid before the procedure was 102,66 cm^3, with the largest lesion treated measuring 837,1 cm^3. The median volume of the dominant fibroid before the procedure in patients with multiple fibroids was 93,22 cm^3, with the largest dominant fibroid treated measuring 464,8 cm^3. The median volumetric reduction rate for the solitary fibroid was 49,38% while the median volumetric reduction rate for the multiple fibroids was 57,38%. We found no

Table 2.

Changes in uterine volume and dominant fibroid volume before and after uterine artery embolization (UAE). The Wilcoxon signed-rank test showed statistically significant difference between preprocedural and postprocedural uterine and dominant fibroid volume (p<0,001).

	Median (cm^3)	IQR (cm^3)	Median volume reduction (IQR)	p-value
Uterine volume before procedure	448,68	258,13 – 722,95	37,51% (25,04 – 55,6)	<0,001
Uterine volume after procedure	247,46	147,37 – 468		
Fibroid volume before procedure	96,64	49,18 – 203,58	55,95% (33,41 – 73,47)	<0,001
Fibroid volume after procedure	41,45	17,38 – 94,16		

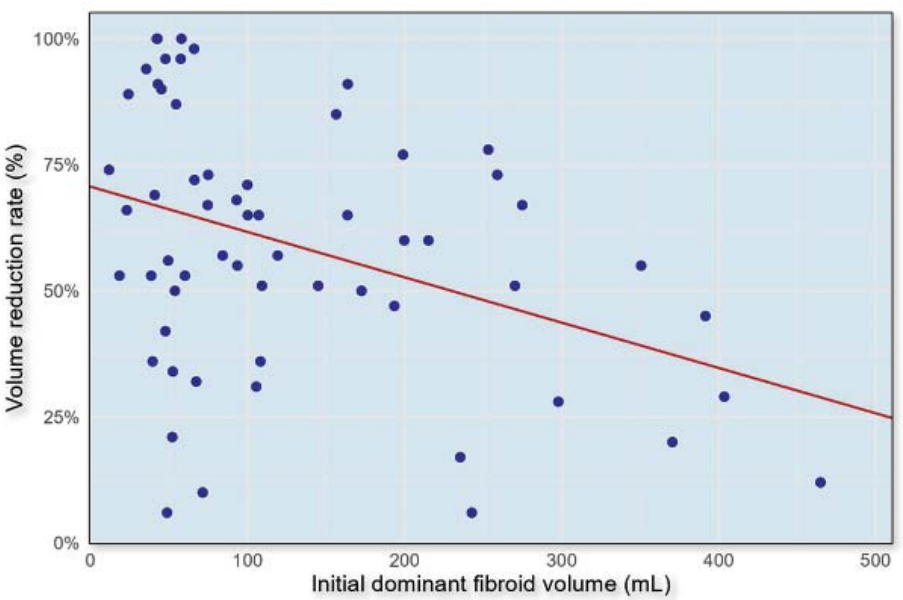

Figure 4. Negative correlation between the preprocedural dominant fibroid volume and dominant fibroid volume reduction (r_s = -.365, p < 0.01)

Table 3.

Fibroid volume reduction after uterine artery embolization compared to FIGO fibroid classification. The Kruskal-Wallis test was used to test significance between the three groups (H = 7,013, p = 0,03), and the Dunns post hoc test was used for multiple comparisons between the groups.

FIGO Classification	Dominant fibroid volume before UAE (cm^3)	Dominant fibroid volume after UAE (cm^3)	Volume reduction (%)	p Value
Submucosal (n = 12) – A				
Median (IQR)	42,36 (26,91 – 67,14)	6,02 (2,38 – 35,74)	80,08% (53,62 – 92,55)	**A-B = 0,014**
Range	11,76 – 259,00	0 – 68,89	9,84% – 100%	
Hybrid (n = 41) – B				
Median (IQR)	157,35 (66,02 – 272,54)	57,79 (24,13 – 192,09)	54,53% (23,78 – 71,46)	**A-C = 0,022**
Range	24,92 – 837,1	0 – 707,16	-323,86% – 100%	
Subserosal (n = 12) – C				
Median (IQR)	63,68 (52,09 – 104,14)	35,47 (27,82 – 64,25)	49,29% (32,66 – 63,02)	**B-C = 0,704**
Range	22,99 – 193,45	2,37 – 102,07	20,58% – 95,87%	

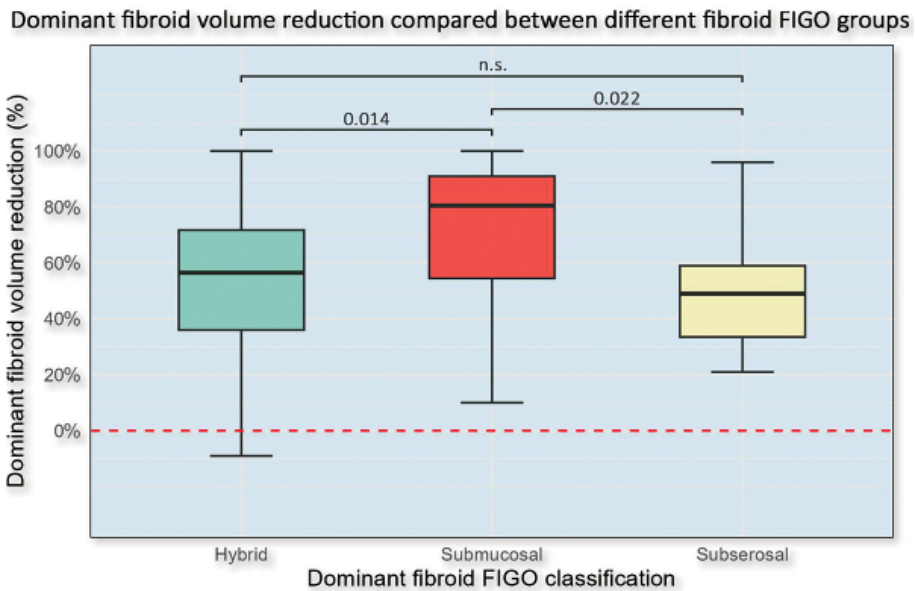

Figure 5. Boxplot of fibroid volume reduction between different fibroids grouped by FIGO classification. Statistically significant volume reduction is seen in submucosal fibroids when compared to hybrid (p = 0,014) or subserosal (p = 0,022).

correlation between the volumetric response rate and the number of fibroids (r_s = .097, p = .219).

DISCUSSION

Our study confirms the efficacy and safety of uterine artery embolization for the treatment of uterine fibroids. The median dominant fibroid volumetric reduction rate was 55,95% after six months. The median uterine volumetric reduction was 37,51%. We had five patients (7%) who had minor complications which resulted in a prolonged hospital stay. In our retrospective analysis, we found in total two patients (3%) who had major complications, of which only one was related directly to the UAE procedure. Our volumetric reduction rates and complication rates are similar to those reported in other studies(19–21). We report no mortalities in our study. Most of the patients had significant symptom improvement.

We found a negative correlation between the initial dominant fibroid volume and reduction

Table 4.

Dominant fibroid infarction descriptive analysis showing no statistically significant differences between the dominant fibroid infarction and initial fibroid volume and number of fibroids (p = .083). The FIGO classification of the fibroids was not correlated with the infarction of the fibroids (p = .298).

Infarction	Median preprocedural dominant fibroid volume (IQR)	Location of the fibroids	Median number of fibroids (IQR)
No (n = 5)	198,94 cm^3 (91,14 – 297,38)	Hybrid = 5 (100%)	3 (1,5 – 5,5)
Partial (n = 12)	167,24 cm^3 (72,17 – 345,45)	Submucosal = 1 (8,3%) Hybrid = 9 (75%) Subserosal = 2 (16,7%)	2,5 (1 – 7)
Yes (n = 48)	74,88 cm^3 (46,37 – 163,67)	Submucosal = 11 (22,9%) Hybrid = 27 (56,3%) Subserosal = 10 (20,8%)	4 (1 – 7,5)

rate. Smaller fibroids showed much better volumetric response than larger ones. Also, we found that there was a total of three fibroid (5%) expulsions and all of them were relatively small in our study ranging from 104 cm^3 to 135 cm^3. Our findings of negative correlation between baseline fibroid volume and procedure response are similar to those found by other authors(22,23). However, some studies found no correlation between these variables(24,25). However, a study by Czuczwar et al. reported a positive correlation, indicating larger fibroids had better volumetric reduction rates(26). Aforementioned study also summarized the results of similar research that analyzed the correlation between initial fibroid volume and reduction rate in the available studies and showed that most of the studies either found no correlation or a negative correlation, showing that their study was the only one with a positive correlation. It is worth mentioning that their patients were only included with intramural fibroids which could be the reason for the different results. These conflicting results may arise from variations in fibroid cutoff size, differences in embolization techniques used and complex pathophysiology of the fibroids, including the location of the fibroids and their classification. Pedunculated subserosal fibroids are found to have an additional vascular supply rendering them less susceptible to the procedure which could have affected results both in our study and other studies(27). It has been shown that volumetric response depends on the FIGO classification or at least localization of the fibroids and this could be the reason why some studies found a correlation and some have not(28). In our study, most of our fibroids are hybrid (61%), while the rest of them are either submucosal (18%) or subserosal (18%) and this relatively small proportion of the submucosal and subserosal fibroids might have influenced the results. It is important for future research to consider this potential factor and when analyzing, exclude any potential biases. Although our study supports the theory that smaller fibroids may result in better outcomes, it should be taken in accordance with other factors and may not be used solely as a predictive factor for the outcome.

According to our results, there is a statistically significant difference between the FIGO classification of the fibroids and their volumetric response. Submucosal fibroids showed the best volume reduction rate at median of 80% which was much greater than hybrid which had the lowest reduction rate at median of 54% and subserosal which had a median of 49% volume reduction. These findings of submucosal fibroids being a predictive factor for procedure response are similar to other published studies(12,22,29,30). Contrary to these conclusions some authors found no significant difference between the location of the fibroid(24,31). However, those two studies had a small sample of submucosal fibroids (4% and 6% submucosal fibroids in respective studies) which might have affected their results. Submucosal fibroids may be more susceptible to UAE due to embolization particles blocking the arteries in the inner part of the myometrium and not at the outer part of the myometrium as it has been shown by

postembolization histological examination of the uterus by Aziz et al. This could render subserosal and more peripheral fibroids less susceptible to UAE(32). Also worth mentioning is that pedunculated subserosal fibroids may have increased blood supply by other sources, such as ovarian arteries, making them also less likely to respond to UAE(27). Submucosal fibroids could also show better results due to them being closest to the endometrial cavity with a chance to get expulsed out from the uterus after a successful procedure. This effect has been seen in our study where we reported a total of three expulsions (5%) and two of them were submucosal and one was hybrid. Other literature findings confirm this(33). Additional possible reason why submucosal fibroids may respond better to UAE is the vascular anatomy of the uterus. The inner layer of the uterus, the endometrium is supplied via blood by spiral arteries which are terminal arteries, or arteries that do not have any anastomoses with other blood vessels, meaning once the embolization is done, it results in the endometrial layer being more vulnerable(34). Nonetheless, our study confirms this theory that submucosal fibroids have better volumetric response than other fibroids and it should be taken into account when considering UAE as a therapeutic option.

We also analyzed the fibroid infarction rate among UAE procedures and found that 74% had complete infarction, 18% had partial infraction and only 8% did not have infraction. These results are similar to those previously published by other authors(35,36). Previous studies reported fibroid infractions only in rates, not considering whether the location or other factors may influence the results. We further analyzed whether there were any differences between the groups and did not find any statistically significant differences. Fibroid location did not seem to influence fibroid infraction after UAE.

The signal intensity ratio on T2-weighted MRI has been found in other studies to be a significant predictive factor for UAE procedure morphologic outcome and volumetric reduction rate. Multiple authors assessed signal intensity on T2-weighted MR images and found that hyperintensity is associated with better volumetric response(37–39). These studies categorized patients into two groups based on fibroid intensity; hyperintensive and hypointensive fibroids. Results of these studies showed that hyperintensive fibroid group had a better volumetric response when compared to hypointensive fibroids. However, this categorization into groups depending on fibroid intensity might introduce bias, as signal intensity ratio is a continuous variable and therefore other authors used correlation analysis which may provide a better understanding of the relationship between signal intensity and volumetric response. Duvnjak et al. and Sipola et al. reported a positive correlation between signal intensity and volumetric response, using Spearman's rank correlation, because they had, similar to our study, only one hypointensive fibroid(13,24). We used Spearman's rank correlation to assess if there were any correlations between signal intensity ratio and volumetric response, but contrary to mentioned studies, our results didn't find any statistically significant results. Higher signal intensity may be due to hypercellularity, increased vascularity, or degeneration of the fibroid and their differentiation may not be easy on T2 MRI, but the heterogeneity of fibroids may help in differentiation between those two(40). Degenerative fibroids predominantly have a high signal intensity ratio on T2WI MRI and their incidence in patients who were referred to UAE varies and was reported to be around 5%(41). Most patients with degenerative fibroids were treated conservatively and understanding the physiology of the degenerative fibroids is important when referring to UAE, as it may result in poorer outcomes. So, these conflicting results may arise from the fact that hyperintense fibroids may show greater response as it may indicate they have increased vascularity and therefore better outcomes when embolized(42). On the other hand hyperintensity on T2WI might be from fibroid degeneration and it has been reported that they may not respond that well to the UAE(43). In our study we found a weak positive correlation between the increase in signal intensity ratio and volumetric response, however, it was not statistically significant. This finding might be due to multiple factors as we didn't consider morphological heterogenicity of fibroids, which might have affected our results. Although some authors did not find a correlation between the heterogeneity of signal intensity and volumetric response it should be considered when analyzing signal intensity ratio as a predictive factor for volumetric response(44). This topic remains quite complex

with many questions open and further research is required with multiple factors such as heterogeneity, postcontrast enhancement and different signal intensity ratios on multiple imaging modalities which might have an impact on the results.

Another analyzed factor was the number of fibroids and whether it affected the procedural outcome. We did not find any correlation between the number of fibroids and the volumetric reduction rate. This same conclusion was drawn by many other authors as well(19,45). It has been found that the presence of multiple fibroids can lead to uterine hypervascularity with increased volume of blood vessels compensating for fibroid vascular uptake. This may be attributed to an increased amount of embolization particles required for a successful procedure(27). However, the number of fibroids in this study did not predict either fibroid or uterine reduction volume.

Our study has several limitations. This is a retrospective analysis from a single center. We assessed procedure results according to the volume reduction in fibroid size, which does not necessarily correlate to improvement in clinical symptoms. In the case of multiple fibroids, only the patients' dominant fibroid was evaluated and included in the current analysis, which might have introduced bias to our results and treatment response. In addition, according to the FIGO classification of fibroids, most of our fibroids were hybrid, which might have affected our results.

In conclusion, this study confirms that uterine artery embolization is a safe and effective procedure for the treatment of uterine fibroids, with a smaller complication rate when compared to surgical options(46,47). In addition to preserving the uterus, UAE offers the advantage of avoiding general anesthesia and surgical complications with a shorter recovery time(48). The influence of various prognostic factors for successful treatment of fibroids, such as initial fibroid volume, signal intensity ratio on T2-weighted MR imaging, location of the fibroid according to FIGO classification, age, and number of fibroids are still a matter of debate, and available data are conflicting. Our study demonstrated that UAE was more successful in patients with submucosal fibroids and smaller baseline fibroid volume, adding further evidence to the current literature that they may be used as a favorable predictor factor for the procedure outcome. Additionally, MRI plays an important role in the diagnosis, characterization, pretreatment planning and postprocedural follow-up. It is also an effective method for predicting volumetric response after UAE, which can be easily incorporated into routine clinical practice. Prediction of treatment outcomes using MRI fibroid characteristics would allow for better patient selection, fewer treatment failures and fewer procedure repeats. Signal intensity on T2-weighted MRI and heterogeneity are showing promising results as predictors of volumetric response, even though our results did not find significant results. Multidisciplinary collaboration between gynecologists and interventional radiologists should be implemented when it comes to treating uterine fibroids.

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Sažetak

EMBOLIZACIJA MIOMA MATERNICE: PREDIKTIVNI MR FAKTORI ZA SMANJENJE VOLUMENA MIOMA

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Cilj ovog istraživanja je bio istražiti utječu li početni volumen mioma, FIGO klasifikacija mioma, omjer intenziteta signala na T2 snimkama magnetne rezonancije i broj mioma na ishod embolizacije uterinih arterija te prikazati 6-godišnje rezultate iz jednog kliničkog centra. Retrospektivno je pregledana medicinska dokumentacija, procedure embolizacije i snimke MR-a kod 74 pacijentice, koje su bile podvrgnute proceduri embolizacije mioma u KBC Sestre milosrdnice između 2017. i 2023. godine. Rezultati su pokazali negativnu povezanost između početnog volumena mioma i redukcije volumena mioma, pri čemu su veći miomi pokazali manju redukciju volumena ($p < 0.001$). Pronađena je statistički značajna razlika između redukcije volumena mioma između pojedinih skupina FIGO klasifikacije. Submukozni miomi pokazali su najbolju redukciju volumena sa statistički značajnom razlikom prema hibridnim mioma i subseroznim miomima. Nije pronađena statistički značajna razlika u redukciji volumena između hibridnih i subseroznih mioma. U istraživanju nije pronađena povezanost između omjera intenziteta signala na T2 snimkama i broja mioma na ishod postupka. Ovo istraživanje ukazuje da su submukozni miomi te manji početni volumen mioma povezani s boljom redukcijom volumena i mogu biti prognostički čimbenik za uspješnost embolizacije uterinih arterija. Zaključno, ovo istraživanje potvrđuje da je embolizacija uterinih arterija sigurna i učinkovita procedura za liječenje mioma maternice.

KLJUČNE RIJEČI: *embolizacija uterinih arterija, lejomiom, magnetska rezonancija*