Microwave Ablation for Symptomatic Uterine Fibroids

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Abstract

Minimally invasive uterine-conserving treatments have been proposed to relieve the symptom and improve quality of life of patients with fibroids. Therefore, it is crucial to use minimally or noninvasive therapy which is safe and could provide a good therapeutic result. The article will review the principles, procedure, outcomes, and complications of microwave ablation of uterine fibroids. The importance of the evaluation pre and post procedure of the patient will be emphasized. At the end of the paper, other techniques about the treatment of symptomatic uterine fibroids are also reviewed.

Keywords

Microwave ablation • Ultrasonography, interventional • Uterine leiomyoma

24.1 Introduction

Uterine fibroids are common benign tumors that arise from the smooth muscle cells of uterus. They are clinically apparent in about 25 % of women [1]. Traditionally, treatment for symptomatic uterine fibroids is hysterectomy which ensures permanent relief of fibroid-related symptoms, but it is associated with significant morbidity and guarantees infertility [2, 3]. Even women without a desire for future pregnancies might not wish to lose their uterus for various reasons. Many patients would like to look for modalities to permanent alleviation of symptoms rather than surgical radical hysterectomy for this benign disease [4].

Minimally invasive uterine-conserving treatments such as laparoscopic myomectomy (LM), uterine artery embolization (UAE), high-intensity focused ultrasound (HIFU), and radiofrequency ablation (RFA) have been proposed [5–8].

Cheng Xiangyun et al. firstly reported transvaginal microwave ablation (MWA) for pedunculated submucosal fibroids into the vagina in 1977 as a minimally invasive treatment [9]. Jing Zhang et al. firstly reported the ultrasound-guided percutaneous microwave ablation (PMWA) as a treatment for symptomatic uterine fibroid in 2007 [10]. Since then, PMWA as a minimally

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invasive management technique has been developed and improved in uterine fibroid therapy within the last several years [11]. Now in clinical, MWA as a treatment for fibroids has been used mainly by ultrasound-guided percutaneous. Hence this article will focus on PMWA. The potential advantages of MW technology include consistently higher intratumoral temperatures, larger tumor ablation volumes, and faster ablation times [12, 13]. This technology has been widely used to treat solid tumors in multiple organs other than the uterus, such as liver, thyroid, lung, kidney, adrenal gland, and so on [14–16].

Since uterine fibroids are benign, treatment is focused on symptom relief, fertility reserve, and quality of life improvement [17]. Therefore, it is crucial to use minimally or noninvasive therapy which is safe and could provide a good therapeutic result. The uterus is adjacent to the rectum and the bladder, so it is important to avoid thermal damage to the adjacent tissues during treatment procedures [18].

24.2 Indications

Patients who are diagnosed as with uterine fibroids by MRI, classified as type 0–6 according to international FIGO classification [19] (Table 24.1) and with the following symptoms:

1. Menorrhagia. Defined as prolonged or excessive bleeding at regular intervals, generally blood loss greater than 80 ml per cycle [20] and the blood routine test showing HGB <110 g/L
2. "Bulk" symptoms. Including excessive pelvic fullness often resulting in urinary tract symptoms (e.g., urinary urgency and frequency), gastrointestinal symptoms (e.g., constipation), and low back pain secondary to pressure
3. Patients younger than 45 years old and have the strong demand to reserve uterus
4. Reproductive dysfunction. Patients who are with infertility due to uterine fibroids and require to give birth after treatment
5. Patients, nulliparous, younger than 30 years old, with average diameter of fibroids >5 cm, though without obvious clinical symptoms and not suitable for treatment under laparoscope and hysteroscope

Table 24.1 The International Federation of Gynecology and Obstetrics (FIGO) classification

Type 0	Pedunculated intracavitary
Type 1	<50 % intramural
Type 2	≥50 % intramural
Type 3	Contacts endometrium, 100 % intramural
Type 4	Intramural
Type 5	Subserosal ≥50 % intramural
Type 6	Subserosal <50 % intramural
Type 7	Subserosal pedunculated
Type 8	Others (specify, e.g., cervical, parasitic)

Type 0 to type 2 fibroids are defined as submucosal fibroids, type 3 and type 4 as intramural, and type 5 to type 7 as subserosal

24.3 Contraindications

1. Menstrual period, gestation, or lactation period.
2. Fibroids enlarge quickly in short time and cannot rule out canceration.
3. Patients with uncontrolled pelvic inflammatory disease.
4. Severe coagulation disorders, platelet less than 50×10^9/L, prothrombin time >25 s, prothrombin activity <40 %.
5. Cancer cells found out by cervix TCT examination.
6. Fibroids classified as type 7 or type 8 according to FIGO classification.

24.4 Evaluation of the Patient for PMWA

24.4.1 Preablation Preparation

All patients considering PMWA require a thorough gynecologic evaluation. The treatment procedures, the expected curative effect, and the potential complications as well as the potential hazardous effect on fertility and adjacent organs are needed to explain in detail to the patients. The applications for treatment and written informed consent will be signed by all the patients. The patients need to take routine blood, urine, and stool examinations along with a test measuring bleeding and clotting time and electrocardiography (ECG).

Contrast-enhanced magnetic resonance imaging (ce-MRI), 2D gray-scale and color Doppler ultrasonography, and pre-contrast-enhanced ultrasonography (CEUS) are performed to evaluate the site, size, and blood supply of the fibroid.

24.4.2 Preclinical Assessment and Imaging

Diagnostic imaging studies are essential not only to confirm the suspected diagnosis of fibroids but also to rule out other malignancies. ce-MRI and transabdominal and endovaginal ultrasounds are extremely helpful in identifying and localizing uterine fibroids. A very small percentage of patients with uterine fibroids will develop leiomyosarcomas (0.2–0.3 %) [21]. If clinical concern for uterine sarcoma exists, image-guided biopsy is indicated.

Women with multiple large fibroids are often adequately evaluated. We devoted specifically to the risk of recurrence after PMWA because of the multiplet [22]; for the sake of safety, we just, in one procedure, ablate the dominant fibroids (the larger fibroids and the main reason of symptoms) and leave alone the smaller ones (<4 cm and not for the symptom reason). For the large type 2 to type 6 fibroids with the diameter >8 cm, we must inform patients the risk of re-ablation, because of the theoretical reason that large coagulation necrosis area may lead to persistent vaginal discharge or bleeding risk.

24.5 MW Ablation Therapy Procedures

24.5.1 Equipments and Procedures

24.5.1.1 MW Tumor Coagulator

A KY 2,000 MW tumor coagulator (Kangyou Medical instruments, Nanjing, China) with a frequency of 2,450 MHz can radiate continuous and pulse MW emission modes. The needle antenna is 15 G in diameter and 20 cm in length. The distance from the aperture of the MW emission to the needle tip is 5–11 mm; the emission aperture is 1 mm. For the antenna, an internal water cycle cooling system is used to lower the temperature of the needle shaft.

24.5.1.2 Sonography System

Using sonography system with a puncture-guided device and low MI contrast-enhanced function. The frequency of the probe is 2.5–4.5 MHz.

The ablation is performed under intravenous conscious sedation. A catheter is inserted and the bladder is filled for a half hour prior to the ablation in order to observe the location of the urinary bladder and its wall before the ablation. The patients receive a supine position. Under ultrasound guidance, if we cannot exclude the possibility of carcinomatous change of fibroid, a biopsy of the fibroid is performed via percutaneous puncture with an 18-gauge core needle for three slips of pathological diagnosis. Along the path of the biopsy, the MW antenna is then inserted into the center of the fibroid. For temperature measurement in real time during the ablation, one thermal couple is placed at a site of 0.5 cm inside the tumor adjacent to the urinary bladder if the fibroid is located at the anterior wall of the uterus, or adjacent to the rectum if the fibroid is located at the posterior wall. The output energy of the MW is set at 50 W. Based on experience from the previous study [23–26] of using MW ablation in vivo griskin, coagulation zones can be induced covering 4.3 cm × 3.1 cm × 2.8 cm (one antenna,50 w, 300 s), 5.1 cm × 3.6 cm × 4.1 cm (one antenna,50 w, 600 s), 5.7 cm × 5.6 cm × 4.8 cm (two antennae,50 w,300 s), and 6.7 cm × 5.9 cm × 5.3 cm (two antennae,50 w, 600 s). A single antenna is used for fibroids with mean diameters <5 cm and with lower perfusion; double antennas are used with an inter-antenna distance of 1 cm for fibroids with mean diameters ≥5 cm or those <5 cm in mean diameter but with rich blood supply. For larger fibroids with mean diameters ≥5 cm, the ablation is first performed using two antennas with 50 W for 300 s, then the antennas are withdrawn by 1 cm for a second ablation. For fibroids with non-spherical volumes, the margin of the thermal field is controlled at the shortest axis diameter, and the antenna is then withdrawn along the long axis or reinserted into the unablated zone for another ablation session. Computer-aided dynamic temperature

measurement of microwave-induced thermal distribution is used during multiple-electrode coagulation [27].

During the ablation, variations in the echo from the fibroid are monitored by real-time ultrasonography. The MW therapy is stopped when the hyperecho (caused by microbubbles generated during MW emission and representing roughly the ablation zone) covers the whole nodule [26] or when the measured temperature reaches 60 °C [27], because temperature correlates well with the extent of the coagulation necrosis to ensure that the tumor tissue is completely necrosed. The surveillance of the three-dimensional margin of the high echo was achieved with 2D imaging through continuous scanning in cross sections. When the MW therapy ended, the CEUS is performed. If the CEUS showed the non-perfusion volume ≥80 %, the treatment can be stopped.

24.6 Post-ablation Care

After the PMWA procedure, the patient is transferred to the recovery room and given immediate oxygen and electrocardiograms (ECG) for 30 min.

After recovery, the patient is transferred to the ward and kept for 12 h under close observation for side effects and complications. During the observation time, the patients have access to painkillers and antibiotics. The necessary conditions will be discussed in another section below.

24.7 Efficacy Assessment and Patient Follow-Up

The therapeutic efficacy of PMWA has been documented by:

1. Assessment of enhanced imaging
2. Volume reduction of the ablated fibroids
3. Dosage of HGB
4. Patients' reported symptom and quality of life (use UFS-QOL to assess the changes of patients' symptoms and quality of life [28])
5. Ovarian function (sex hormone and fertility)
6. Recurrence or reoperation
7. Adverse reactions and complications

The patients' menstrual information during the first few days after PMWA were recorded. Patients are requested to come back for a recheck at regular intervals thereafter (3, 6, and12 months and then 1 year). An ultrasound scan, appropriate blood work, and the UFS-QOL assessments were obtained at every follow-up visit. MRI and CEUS are the imaging modalities of choice after PMWA [29]. Generally speaking, submucosal fibroids have a higher chance to discharge necrotic masses and larger discharged tissue volume than intramural fibroids, while the subserous uterine fibroids are nearly impossible to discharge necrotic masses because of no connection with the vagina [30]. There are reports of women with pedunculated subserosal fibroids who have sloughed necrotic fibroids into the pelvis after UAE [31, 32]. Hence, we do not recommend PMWA for fibroids of this type. The long-term effect of PMWA on ovarian function has not been completed understood; however, studies on ovarian-related hormone and effects on fertility are under way.

24.8 Possible Adverse Effect and Complications of PMWA and Defensive Measures

24.8.1 Infection and Fever

Strict aseptic manipulation could reduce the risk of hospital-borne infections, while large area of necrotic tissue may lead to absorption fever. If the fever is caused by infection, we can give no special handling except for drinking more water. Otherwise, some measures can be taken.

24.8.2 Pelvic Pain

Use the visual analog scale to assess the pain. If the score is higher than 5–6, painkiller could be used.

The visual analog scale (VAS) is a line 10 cm in length with each end anchored by extreme descriptive. Patients are asked to mark on the line that represented their level of perceived pain intensity [33].

24.8.3 Watery Vaginal Discharge or Colporrhagia

Reduce the risk of uterine infection. When the symptom lasts for a short time, instruct the patients to pay attention to sanitation, and generally, the symptom would disappear automatically. If not or the fluid has smell, some clinical intervening measure must be taken.

24.8.4 Skin or Vaginal Mucous Membrane Burn

For skin security, water-cooled microwave ablation instrument has been applied in clinical to protect skin burn. We can stuff several vaginal yarn balls doused in physiological saline before PMWA which can protect the vagina mucosa from the hot liquid discharged from vaginal.

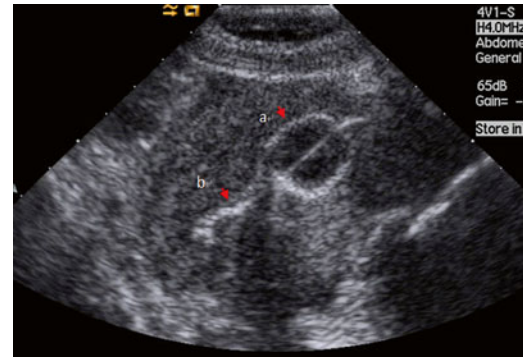

Fig. 24.1 Percutaneous microwave ablation (*MWA*) in a 29-year-old woman with two type 3 fibroids with the sizes of 3.4×3.1 cm and 4.2×4.8 cm who was nulliparous. Because the fibroids are in contact with the endometrium, some defensive measures were taken to protect the endometrium. A 5 F double-lumen balloon urinary catheter was placed into the cavity. The balloon was filled with 1.5 ml of saline solution (*arrow a*). Then, 1 ml sterile ultrasound gel was slowly injected through the urethral catheter to mark the endometrium (*arrow b*). On the same section of ultrasound, the fibroids cannot be shown

24.8.5 Transient and Permanent Amenorrhea

Protecting the endometrium is considered as the core measures. Some defensive measures can be taken. A 5 F double-lumen balloon urinary catheter is placed into the cervix under direct visualization. The balloon is filled with 1–1.5 ml of saline solution to fix the catheter and prevent saline backflow. Then, 1 ml sterile ultrasound gel is slowly injected through the urethral catheter. Endometrium can be marked and covered with this "protective film" from microwave heat by taking this exploratory measure. However, it is presently on its trial stage (Fig. 24.1).

24.8.6 Uterine Perforation or Injuries to Adjacent Organs

First, before PMWA, nursing crux includes gastrointestinal preparation. Second, fill the posterior vaginal fornix with gauze rolls soaked in sterile physiological saline, which play a role similar to uterine manipulator. Third, if the fibroids are close to the intestine or the patient has a retroverted uterus, the investigator can puncture the posterior vaginal fornix then inject sterile physiological saline into the uterus-rectum nest before ablation to separate the fibroids from the surrounding tissue to protect the adjacent organs from heat.

24.9 Results

PMWA is a minimally invasive technique for the treatment of uterine fibroid and adenomyosis by inducing tissue necrosis through heat. Most of the heat generated during MWA was accounted for the rotation of dipole molecules. The preablation 2D grey-scale US showed fibroids of low echogenicity and CEUS showed enhancement within the fibroid. Immediately after MWA, the 2D grey-scale US showed the scheduled treated area was covered with hyperechoic zone and the CEUS showed no enhancement in the ablation zone and with circle enhancement in the periphery of the fibroid (Fig. 24.2). The preablation ce-MRI showed the fibroid was obviously

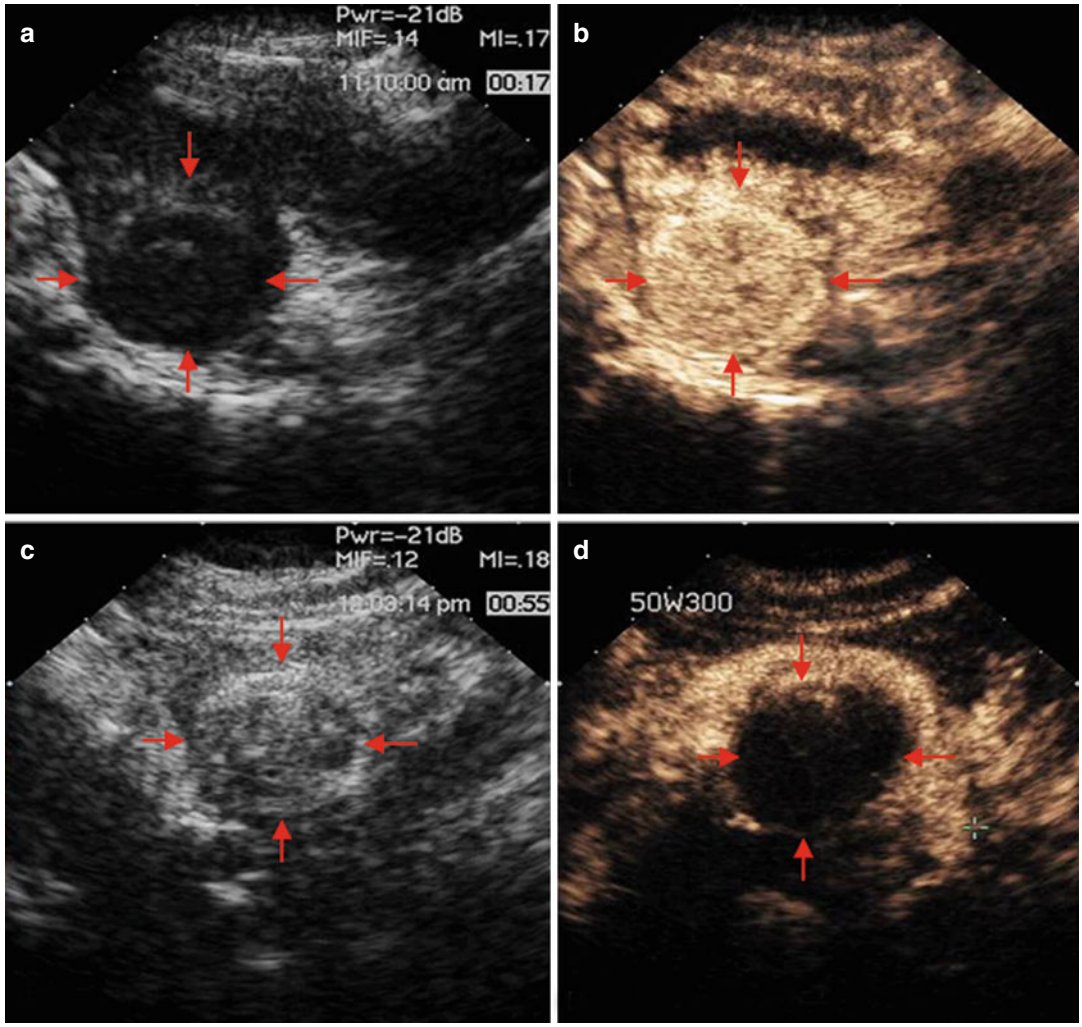

Fig. 24.2 Percutaneous MWA in a 31-year-old woman with a single subserous fibroid in posterior uterine wall. (**a**) Preablation two-dimensional gray-scale ultrasonography shows the hypoechoic fibroid (*arrows*) with the size of 4.4×4.9 cm. (**b**) Pre-contrast-enhanced ultrasonography scan obtained during the early phase after contrast injection, and at 17 s it shows homogeneous hyper-enhancement (*arrows*). (**c**) Two-dimensional gray-scale immediately after MWA shows the scheduled treated area is covered with hyperechoic zone (*arrows*). (**d**) Post-contrast-enhanced ultrasonography immediately after microwave ablation shows the ablation area is consecutively non-enhanced (*arrows*)

enhanced (Fig. 24.3). After the ablation, ce-MRI showed no enhancement in the ablated zone like "black hole." Several studies have been reported. The results are listed in Table 24.2. All of them used US to evaluate the fibroid volume. A paper published in 2011 [18] showed the shrinkage rates of the fibroid were 61.8 %, 78.7 %, 73.2 %, and 93.1 % at 3, 6, 9, and 12 months after ablation, respectively. 15 % (6/40) of patients felt pain in their lower abdomens or waists within 12 h post ablation, and the discomfort rapidly disappeared. 17.5 % (7/40) of patients had a small amount of vaginal bloody secretions within 1–2 weeks after treatment, and they recovered from the bleeding without any therapy after 1 week.

Based on our previous study, from October 2007 to October 2013, 240 patients were treated

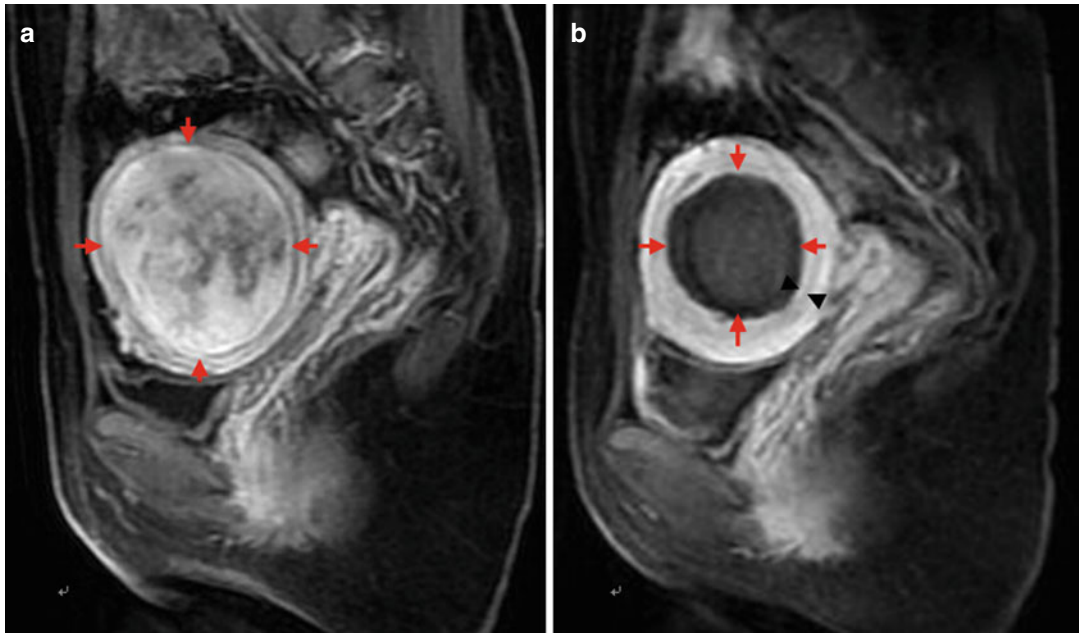

Fig. 24.3 Percutaneous MWA in a 39-year-old woman with an intramural fibroid who suffered from menorrhagia and refused surgical treatment.MWA was implemented to relieve her symptom. (**a**) Preablation sagittal T1W1 contrast-enhanced magnetic resonance imaging (ce-MRI) scan showed one enhancement intramural fibroid (*arrows*) with the size of 7.9×6.9 cm. (**b**) Scan obtained 3 days after ablation shows the ablated fibroid (*red arrows*) without enhancement shrink to 4.9×4.5 cm, which is surrounded by the unablated belt (*black arrows*) with 0.5 cm in width

Table 24.2 Shrinkage rates of the fibroids treated by microwave ablation

Study	Number of fibroids	Baseline (cm^3)	Shrinkage rates of the fibroids			
			3-month	6-month	12-month	24-month
Zhang et al. [18]	40	140.1 ± 87.4	61.80 %	78.70 %	93.10 %	N/A
Qu et al. [34]	17	137.6 ± 61.3	N/A	N/A	44.70 %	N/A
Chunying et al. [35]	20	69.3 ± 7.3	N/A	75.20 %	N/A	N/A
Jun et al. [36]	16	47.8 ± 26.0	57.30 %	66.80 %	79.90 %	92.50 %

N/A not available

with PMWA in our departments (22 patients with 22 submucosal fibroids, 128 patients with 157 intramural fibroids, and 90 patents with subserosal 120 fibroids). 239 patients completed the therapy in a single ablation. One with a large fibroid diameter of 10.2 cm underwent two steps of PMWA to ensure the safety (4 months between two treatments), and the outcomes are satisfactory. All the patients with submucosal fibroids and 30 ones with intramural fibroids had iron deficiency anemia. The dosages of HGB are all recovered normally at mean 6-month follow-up.

Patient-reported symptom severity decreased from baseline (56.3 ± 19.3) to 24 months (11.8 ± 6.9), and health-related quality of life improved from baseline (50.0 ± 10.8) to 24 months (86.0 ± 12.3).

Two (0.8 %) patients encountered recurrence at 9-month and 13-month follow-up respectively and received re-ablations (recurrence is defined as the appearance of a fibroid on ultrasound examination or identification of fibroid during subsequent surgery after the initial ablation [37]).

Fifty-one patients in 240 women (21.3 %) passed necrotic fibroids at approximately 1-day

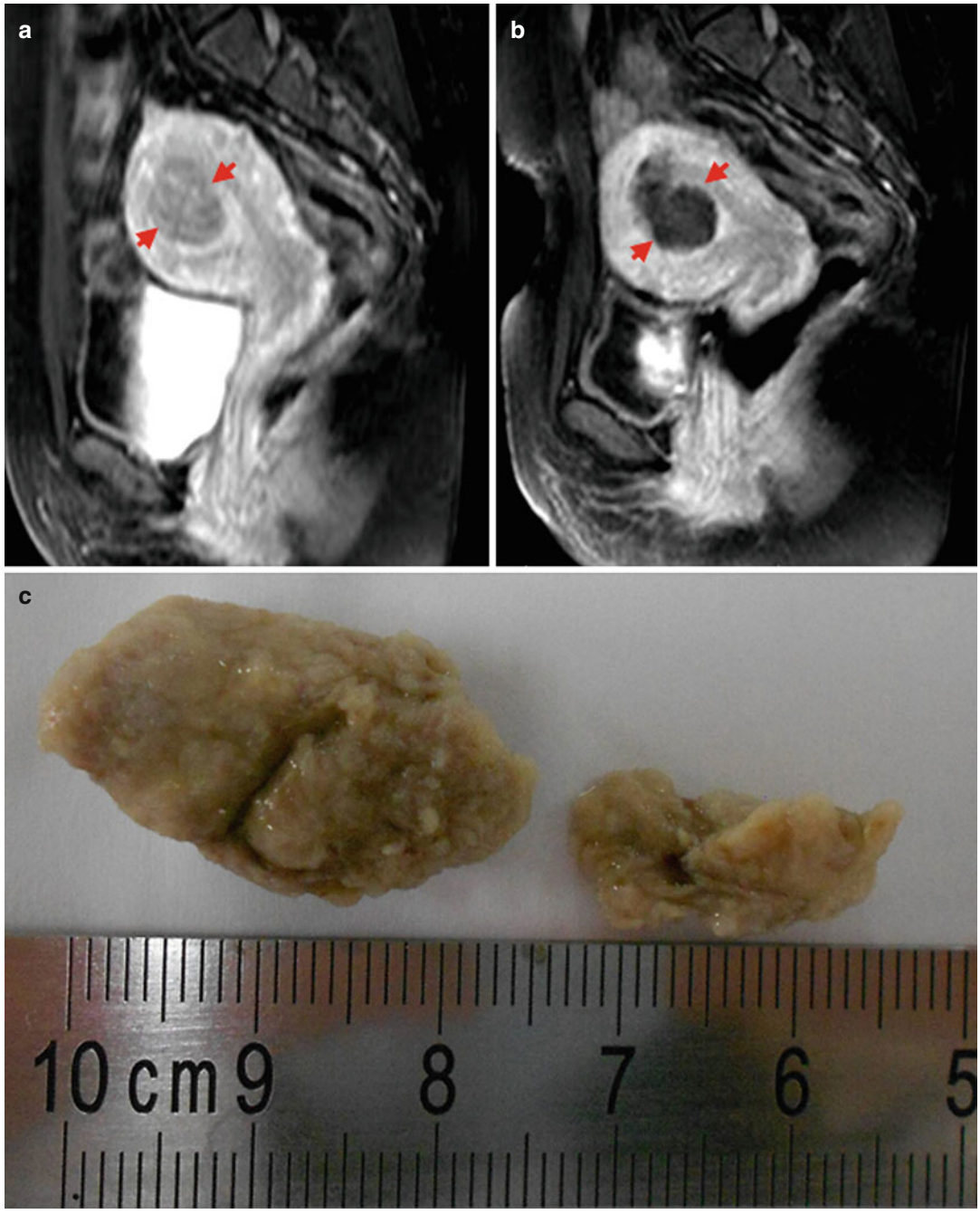

Fig. 24.4 Percutaneous MWA in a 37-year-old woman with a submucosal fibroid who suffered from menorrhagia and refused hysteroscopic myomectomy. MWA was implemented to relieve her symptom. (**a**) Preablation sagittal T1W1 ce-MRI scan showed one enhancement submucosal fibroid (*arrows*) with the size of 3.9×3.3 cm. (**b**) Scan obtained 3 days after ablation shows the ablated fibroid (*arrows*) without enhancement shrinks to 3.5×3.3 cm. (**c**) Two pieces of tissue discharged from vagina with the menstrual blood 1 month after the ablation, then the symptom of menorrhagia was relieved

to 24-month follow-up (Fig. 24.4) (21 patients (95.5 %) with submucosal, 30 (23.4 %) patients with intramural fibroids, and 0 (0 %) with subserous fibroids).

Now, no studies of the impact of PMWA on ovarian function have been published. However, there were five spontaneous pregnancies in four women (one woman conceived twice) in our departments. Two women delivered full-term healthy babies at 13-month and 26-month follow-up respectively. Wang Xiuli et al. [38] have reported that a 29-year-old woman with a fibroid 9.2 cm × 8.7 cm became pregnant and had normal full-term infant at 1-year follow-up.

Two (0.8 %) patients with fibroid >10 cm suffered from colporrhagia 10 days and 20 days after ablation respectively; however, the ce-MRI showed good imaging results but the symptoms persisted. They chose the transabdominal myomectomy to remove the ablated fibroids 20 days and 25 days after ablation respectively. One (0.4 %) patient with a 6 cm submucosal fibroid suffered from severe pain caused by lesion discharging from vagina 7 days after ablation and received an emergency hysteroscopy for removal of the large piece of necrotic tissue. Twenty eight (11.7 %) patients encountered lower abdominal pain in which eight patients got 6–8 scores and took painkillers. No measures were taken to the other 20 patients. Fourteen (5.8 %) encountered absorption fever with normal blood routine results. Fifty-seven (23.8 %) encountered watery vaginal discharge, and symptoms persisted for 3–10 days. No severe complications such as uterine perforation or injuries to adjacent organs happened.

24.10 Discussion

24.10.1 Multi-technology Comparison of Uterine Fibroid Treatment

For decades hysterectomy has been the main therapeutic option available to women with fibroids, and this diagnosis is verifiable at tissue examination of the removed uterus. However, as imaging and minimally invasive diagnostic methods are pursued and developed, new and less aggressive therapeutic options are introduced including LM, UAE, HIFU, RFA, PMWA, and so on.

Following the initial application of LM in 1979 by Semm [5], this minimally invasive technique has become more and more popular worldwide. The procedures include excision of the fibroid(s), repair of myometrium, and removal of the fibroid from the abdomen [39]. Landi et al. [40], in a prospective large sample study, evaluated 368 women undergoing LM. Their mean operating time was 100.78 + 43.83 min, mean decreases in hemoglobin and hematocrit were 1.38 + 0.93 and 4.8 + 2.9 g/100 ml, respectively, and the mean length of hospital stay was 2.89 + 1.3 days. They reported 12 (3.34 %) intraoperative complications, with an intraoperative transfusion of autologous blood required in ten patients. Recurrence rates reported in recent studies ranged from 20.3 % to 22.9 % [41] and the risk of recurrence appears to increase with multiple fibroids and nulliparity [42].

UAE was first introduced in 1974 [6] and involves femoral artery catheterization and intra-arterial infusion of embolization particles, producing ischemia of the fibroid uterus and subsequently decreasing the volume of fibroids [43, 44]. The treatment of symptomatic uterine fibroids is in evolution. Since the Ravina et al. [45] description of UAE as an effective treatment potential, numerous short- and long-term studies have validated the safety, efficacy, and benefits of the procedure when compared with traditional surgical options. All large studies including comparative trials between UAE and hysterectomy have reported 70–90 % symptom improvement for menorrhagia, pain, and bulk-related symptoms, with the mean decrease in the fibroid volume of 42–64 % at 6 months [46–49]. Its major side effect is severe pain after the procedure; other complications include radiation risk (exposure amounts of approximately 20 cGy of radiation), severe infection leading to hysterectomy (1.5 %) and ovarian failure, and low-grade fevers

due to the ischemic necrosis; nausea and vomiting are also not uncommon with postembolization syndrome [50–55].

HIFU refers to the use of tightly focused high-energy ultrasound waves to induce focal thermal effects, ablation, or thermocoagulation in vivo [53]. Some clinical trials showed that there is a correlation between amount of treated fibroid volume and lower likelihood of subsequent treatments: the greater the treatment volume, the better the response achieved [53]. In the study of Stewart [56], 109 patients underwent HIFU and less than 10 % of fibroid volume was ablated. The results showed that 71 % of patients reached the targeted symptom reduction at 6 months with a 13.5 % reduction in fibroid volume, and 51 % reached this point at 12 months. However, in the report by Gorny KR [57], the mean percent of non-perfused volume ratio was 45.4 % immediately upon completion of HIFU treatment. At 3 months' follow-up, 85.7 % reported symptom improvement and 13.3 % reported no symptom relief. At 6 months' follow-up, 92.9 % reported symptom improvement and 7.1 % reported no relief. At 12 months' follow-up, 87.6 % reported overall symptom improvement and 12.4 % had no improvement. The rate of side effects is generally low, including skin burns, lower abdominal pain, nerve palsy, and so on [58].

Ablation of solid tumors with RFA results from heating that is produced when ions follow the oscillations of a high-frequency alternating electric field, and the heat causes coagulation necrosis of local tissue [59]. Guido et al. [60] reported on 124 patients treated with RFA, which had the largest sample size by far. One hundred twelve subjects were followed through 24 months. Patient-reported symptom severity decreased from baseline (61.1 ± 18.6) to 24 months (25.4 ± 20.6), and health-related quality of life improved from baseline (37.3 ± 19.1) to 24 months (79.3 ± 21.7). Iversen et al. [61] reported their experience treating 43 fibroids with RFA; improvements in fibroid symptoms and quality of life were measured by the uterine fibroid symptom and quality of life questionnaire scores at baseline, and 3, 6, and 9 months after the intervention, mean symptom severity scores decreased from 60.7 ± 17.8 to 31.2 ± 19.5. The total health-related quality of life score improved by 46.4 % from 55.6 ± 20.9 to 81.4 ± 16.6. The studies showed that RFA of uterine fibroids is an effective and safe minimally invasive treatment.

To date, the only indications for total LM are pedunculated and subserosal lesions sometimes can even be used for intramural fibroids, depending on the position of the fibroid and the skills of the surgeon. It is believed that subserosal pedunculated fibroid is a relative contraindication to UFE, PMWA, and RFA because of the risk of separation from the uterus. That is, the potential for stalk necrosis and detachment of the leiomyoma could lead to peritonitis, persistent pain, or infection. Compared with LM, UAE, and HIFU, RFA and MWA have many advantages, such as less blood loss, faster recovery, diminished postoperative pain, and shorter hospital stay (Table 24.3). LM and UAE are associated with more and severer complications than RFA and PMWA (Table 24.3). HIFU is a noninvasive therapy for treatment of uterine fibroids and had better cosmetic effects, but it can treat only one fibroid at a session, and one treatment procedure lasts up to 3 h. A large area of necrosis can be achieved in a single access with MWA, and therefore, compared to the other therapy, it is relatively time efficient. When a greater percentage of a fibroid's volume is ablated, symptomatic relief is more pronounced and quality of life increases. Hence improvement of symptoms is different in different research centers because of the different lesion volume reduction.

Table 24.3 Comparison of minimally invasive therapeutic options for fibroid

Author	No. of pts	Therapy	Operating time (min)	Blood loss (ml)	Recovery time	Reduction in fibroid volume (%)			Improvement of symptoms (%)		Major complications (%)
						6-month	12-month	24-month	Within 1 year	Over 1 year	
Landi et al. [40]	368	LM	100.7 ± 43.83	N/A	10.58 ± 6.68 days	N/A	N/A	N/A	N/A	N/A	4.7
Holzer et al. [62]	19	LM	99 ± 37	71 ± 80	2.9 ± 1.8 weeks	N/A	N/A	N/A	N/A	N/A	N/A
Volker et al. [49]	88	UAE	N/A	N/A	N/A	42.1	54.5	60.5	88.9 ~ 91.3	96.3	4.7
Hehenkamp et al. [63]	81	UAE	79	30.9	2.0 days	N/A	N/A	N/A	N/A	N/A	8.64
Ren et al. [64]	145	HIFU	N/A	N/A	N/A	47.9	50.3	N/A	85.5	N/A	4.1
Iversen et al. [61]	43	RFA	N/A	N/A	N/A	N/A	64.7 ~ 78.4	71.4 ~ 82.7	64.3 ~ 76.2	N/A	0
Ghezzi et al. [65]	25	RFA	20 ~ 45	N/A	N/A	68.8	77.9	77.9	N/A	N/A	0
Zhang et al. [18]	240	MWA	8 ~ 12	N/A	N/A	82.9	78.70	93.10	N/A	N/A	2

LM laparoscopic myomectomy, *UAE* uterine artery embolization, *HIFU* high-intensity focused ultrasound, *RFA* radiofrequency ablation, *MWA* microwave ablation, *N/A* not available

Conclusion

A marked shrinkage in post-fibroid volume and a novel improvement on symptom and quality of life are some of the benefits achieved. Totally the technique is a safe, feasible, and effective minimally invasive therapeutic option in the management of women with symptomatic uterine fibroids. The risk of transient or permanent menopause appears related to the age of the patient at the time of ablation. Further studies will hopefully provide us with answers to many questions, including the optimal population groups, the durability of the procedure, and the influence on ovarian function and fertility.

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