HIFU Ablation

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Ultrasound monitoring is the method to apply diagnostic imaging technology to guide the treatment of high-intensity focused ultrasound (HIFU). The treatment is called ultrasound-guided HIFU (USgHIFU) ablation surgery. Compared with focused ultrasound ablation surgery guided by magnetic resonance (MRgHIFU), HIFU under ultrasound monitoring is less expensive. Besides, ultrasound monitoring can also provide real-time image monitoring of changes in uterine position and bowel movement during the ablation procedure. The therapeutic effect can be shown by the gray-scale changes at the target lesions during HIFU ablation. Under ultrasound monitoring, all these gray-scale changes, absence of Doppler blood flow, and non-perfusion of ultrasound contrast agent at the adenomyosis lesion will indicate the effects of HIFU; thus, it is a reliable monitoring indicator [1]. In addition, ultrasound monitoring is quieter, and patients do not need to be in a relatively enclosed treatment environment, like in an MRI room. Therefore we are illustrating the use of a USgHIFU ablation system, which is more popular in China. In this chapter, we will introduce the preoperative preparation and the therapeutic process of focused ultrasound ablation surgery for adenomyosis.

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14.1 USgHIFU Treatment Procedure

14.1.1 Preoperative Preparation

(a) Ultrasound simulation assessment: Before surgery, the patient should have a simulation assessment on the ultrasound treatment system, to determine whether the ultrasound energy pathway, i.e., the acoustic pathway, is safe, whether the lesion can be displayed, and whether the target focus can reach the lesion; for patients with IUDs, they should have the IUD removed. Patients should have finished their menses and have no vaginal bleeding before the HIFU ablation. At the time of the assessment test, the patient needs to be able to retain her urine and tolerate a large bladder volume. Routine blood investigations include liver and kidney functions, complete blood count, and coagulation profile, and, if necessary, the pregnancy test, Pap smear (TCT), and high vaginal swab culture are performed. For patients with hypertension or with a history of chest pain, chest X-ray and an electrocardiogram are done to assess their cardiovascular condition. Finally, a pelvic MRI examination before the assessment should be available to assess the adenomyosis lesion in detail, and the MRI image can be incorporated into the ultrasound image to guide the HIFU ablation.

Patients with irregular vaginal bleeding need to undergo an endometrial biopsy to exclude endometrial lesions, and patients with severe anemia should be given an iron replacement or blood transfusion if the hemoglobin is less than 7 gm/dL. Even for those who have no contraindication for HIFU surgery, it is preferable to admit her to the hospital the day before the operation for preoperative preparation, signing consent, and communicating issues related to the HIFU surgery.

(b) Preoperative bowel preparation: Patients need strict preoperative diet preparation, usually 3 days before surgery; they should take a residue-free diet and easily digestible food, drink senna water to induce diarrhea 2 days before treatment, and full-liquid diet 1 day before treatment but no gas-producing foods, such as milk, soy milk, etc. Patients need to use compound polyethylene glycol electrolyte powder (or other cathartic drugs) to promote the elimination of intestinal contents in the afternoon on the day before treatment. The night before and the morning on the day of treatment, the enema exudates should be clear with no solid matters. During the bowel preparation, treatment, such as electrolyte supplementation and fluid replacement, can be given, particularly in older women or women with some medical illnesses.

(c) Skin preparation, degreasing, and degassing of the skin in the area within the acoustic pathway, including the skin below the navel, pubic symphysis, and perineal skin; no hair is left within the ultrasound energy pathway, and care should be taken not to create abrasions or wounds on the skin. Before treatment, further communication and psychological counseling with the patient will reduce their tension and anxiety.

14.1.2 Treatment

14.1.2.1 Administration of Sedation and Analgesia

The purpose of sedation and analgesia is to enable patients to tolerate any unpleasant surgical procedure, eliminate patients' anxiety and tension, and reduce the reaction to pain. It allows patients to maintain a certain level of consciousness to reflect the feelings correctly and respond to the doctor's and nurse's instructions during the surgery. During the operation, the patient's heart rate, blood pressure, respiratory rate, and blood oxygen saturation are monitored by an electrocardiogram monitor.

Many anesthetists have their protocols to provide sedation and analgesia according to their experience. They will use the same drugs according to their preference for sedation and analgesia. However, they usually tailor the drug according to the needs of patients and titrate the dosages based on her sedation level. In the absence of anesthetists, a similar program from different centers can be given to the patient as advised by their anesthesiology department. During the sedation and analgesia medication, closely observe the patient's heart rate, blood pressure, respiratory rate, and blood oxygen saturation.

14.2 Therapeutic Equipment

The USgHIFU treatment described in this book is based on a focused ultrasound tumor therapeutic system JC 200 model manufactured by Chongqing Haifu Medical Technology Co., Ltd. It operated with a treatment frequency of 0.94 MHz with a focal length of 138 mm. The HIFU tumor therapeutic system JC 200 is shown in Fig. 14.1. It has a transducer with a 20-cm diameter to produce ultrasound energy, with an ultrasound imaging probe (My-Lab70, Esaote, Italy) incorporated within the center of the transducer. The ultrasound probe enables real-time sonographic monitoring during HIFU ablation.

During the treatment process, the patient lies prone on the HIFU treatment bed, under conscious sedation (Fig. 14.2).

Fig. 14.1 The HIFU tumor therapeutic system JC 200. The ultrasound transducer and controller platform, with the ultrasound monitoring probe fixed at the center located under the treatment bed

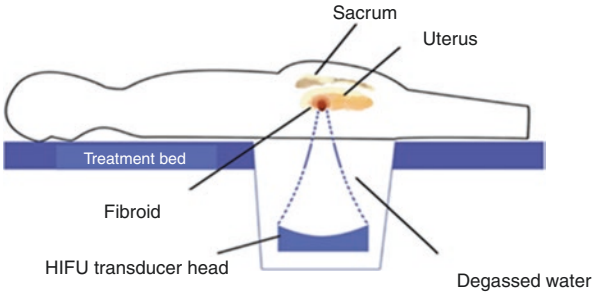

Fig. 14.2 HIFU ablation of adenomyosis with a patient lying prone on the treatment bed. The HIFU transducer was mounted under the treatment bed, as shown

Fig. 14.3 JC 200 computer console to operate the USgHIFU ablation for adenomyosis

A urinary Foley catheter is required in the patient's bladder to control the bladder volume and to adjust the uterine position. The skin of the patient's abdomen is now placed in contact with cold (at 10 °C) degassed water. A computer console (Fig. 14.3) is to monitor the treatment by real-time ultrasound scan and to control the therapeutic ultrasound transducer platform for a six dimension movement.

With the six dimension movement of the transducer, together with the central ultrasound probe, the location, size, and shape of the uterus and the adenomyosis lesions are identified on the ultrasound image. A real-time ultrasound scan is to determine the location of the uterus in a sagittal view.

The following procedures will be performed for adenomyosis ablation.

1. Before the HIFU ablation, microbubble angiography with a microbubble contrast agent (SonoVue, Bracco, Italy) is performed before the start of treatment and at the end of treatment to assess the extent of the ablated area (Fig. 14.4). The ablation treatment can begin 10 min after the infusion of ultrasound microbubble contrast agent, to avoid HIFU causing microbubble-induced injury.
2. Before the start of the treatment, the sagittal plane of the uterus or adenomyoma is scanned; a treatment plan is made by dividing it into many slices with a thickness of 5 mm each from its left to the right ends.

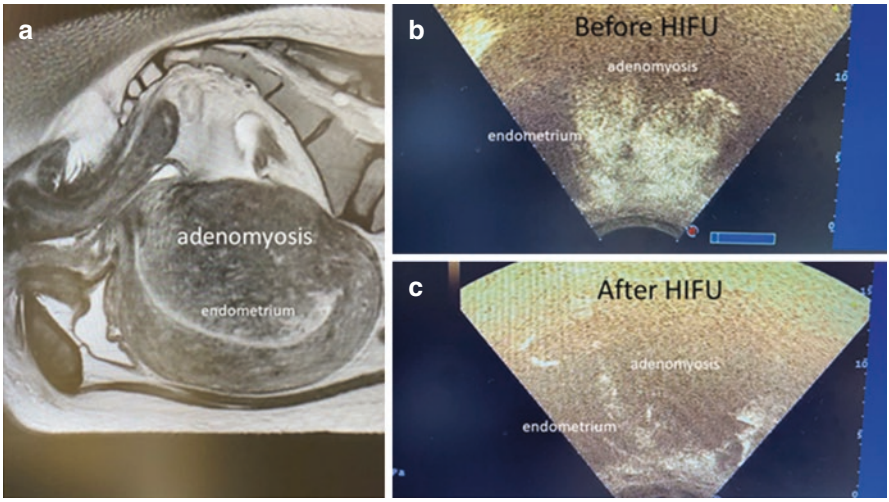

Fig. 14.4 (**a**) MRI image demonstrated posterior adenomyosis in the uterus; the endometrium was visible. (**b**) IV Infusion of microbubble before HIFU ablation, an ultrasound contrast agent, to visualize and estimate the sizes of the adenomyosis lesion. The endometrium was shown to be more intense perfused with microbubble (**c**) After HIFU ablation, non-perfusion areas of adenomyosis lesion can now be estimated, with the endometrium still intact, showing microbubble perfusion

3. Under the therapeutic parameters based on the locations, sizes, and vascularity of the adenomyosis lesions, the ultrasound energy emitted from the therapeutic ultrasound transducer passes through the skin into the body, focusing on the adenomyosis lesion through a pool of circulating cooled degassed water. The adenomyosis lesion on each slice should be ablated from the deep part before finally to the superficial part of the lesion, and this process is repeated slice by slice to achieve treatment of the entire adenomyosis lesion. The HIFU ablation can be guided by an MRI image incorporating into the real-time ultrasound image so that the target area can be easily visualized and provide more safety (Fig. 14.5).
4. Due to the fixed focal length and size of the focused ultrasound transducer, the HIFU ablation target may need to be adjusted by positioning a degassed water bag between the abdomen and the HIFU transducer. In this way, some superficial lesions can be reached.
5. During ablation, it is important is to establish a safe acoustic pathway without any gas bubble or small bowel within the pathway. By adjusting the size of the degassed water bag, increased filling of the bladder with normal saline or increased pressure on the abdomen by the ultrasound transducer or ultrasound probe; this can help to push the small bowel away from the front of the uterus, to establish a safe acoustic pathway, and to avoid bowel injury and damage to other non-target tissues.

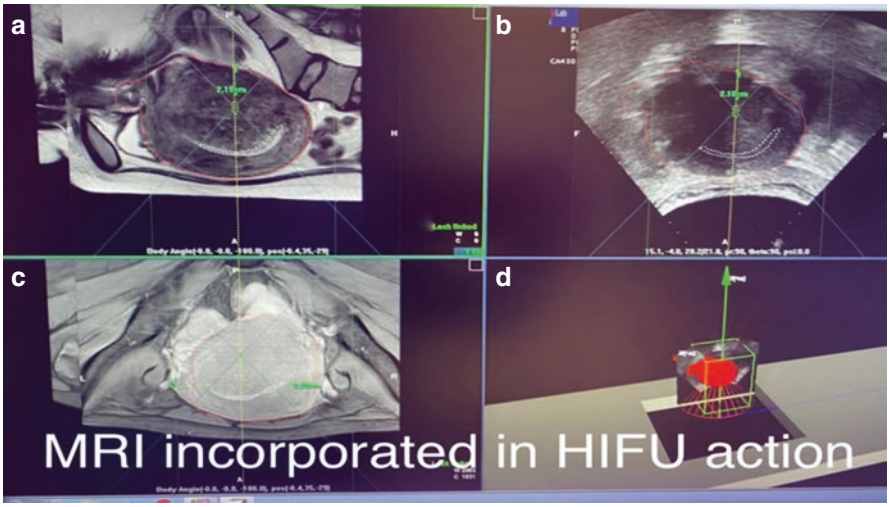

Fig. 14.5 The MRI image of the adenomyosis and its incorporation into the ultrasound image during HIFU ablation. (**a**) Sagittal MRI image with uterine and endometrial outlines marked out. (**b**) These MRI outlines were incorporated into the ultrasound image during HIFU ablation treatment. (**c**) Transverse MRI image in the pelvis (**d**) 3D positioning of the target lesion for easy location of the HIFU target

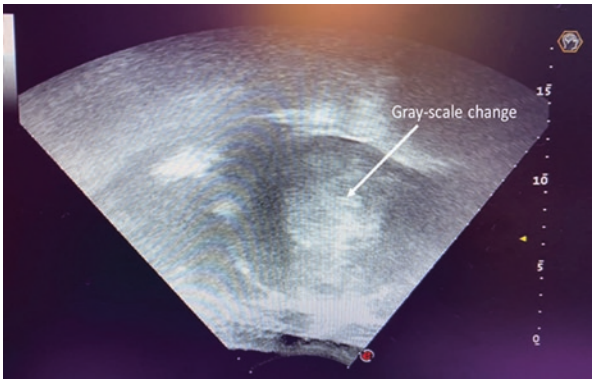

Fig. 14.6 Ultrasound monitoring of HIFU treatment with lesion showing gray-scale change during HIFU ablation

6. The ultrasound energy power used is adjusted to 300–400 W, with energy intermittently applied. Each energy exposure lasts for 1 second with a rest period of 3 seconds. HIFU sonication continues at a spot when a gray-scale change appears or up to a defined time of sonication (Fig. 14.6).
7. The target point of the focused ultrasound is to ablate the adenomyosis lesion slice by slice, and each time the focus is positioned with a safety margin of 1–1.5 cm from the uterine serosa and the endometrium. The ablation procedure starts at the central slice. When there is a significant increase in gray-scale change, the target focus will move to the next area, then the next layer for treatment, and the treatment is completed when the gray-scale change occurs in

each slice of the lesion to be ablated. The diagnostic ultrasound probe is used to monitor the gray-scale changes in the target lesion and the patient's movement, if any.

8. Cautions are taken to avoid sonication ablation close to the endometrium and serosa of the uterus. This protocol will help to minimize the thermal injury to the endometrium and surrounding tissues situated next to the uterus. During the HIFU procedure, the target location, energy power, sonication time, and treatment interval should be adjusted according to the patient's complaint or response. Any pain experienced by the patient at the time of treatment should alert the doctor of any potential risks of nerve or skin injury, with appropriate prompt management. Therefore it will reduce the risk of skin burns and nerve damage [2].
9. After the end of the HIFU procedure, the volume of the ablated lesion is roughly estimated by the non-perfusion volume during a repeat microbubble infusion, i.e., lesion areas not filled with contrast agents.
10. After the surgery, the patient should lie prone, and catheterization is maintained for another 1–2 h. The abdominal skin was given ice compress, if the patient is complaining of skin hotness. Other treatments, such as analgesic, antibiotics, and fluid replacement, if necessary, can be given. Keep observation of the patient's postoperative side effects closely for appropriate and timely treatment.

The patient can complete the treatment of HIFU in a relaxed and pleasant environment. The entire process does not create open wound or keyhole wounds, with no bleeding or general anesthesia, and the patient can mobilize immediately after HIFU treatment. After the patient finishes HIFU treatment, she is kept in the observation room for 1–2 h (non-inpatients) or stay in the hospital until the next day for observation. If the vital signs are stable and there is no obvious discomfort, they can be discharged home and leave the hospital.

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