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Advances in MRI Assessment of Pelvic Space Changes Following Ultrasound-Guided High-Intensity Focused Ultrasound Ablation of Uterine Fibroids

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Abstract

Uterine fibroids remain a prevalent condition among women of reproductive age, imposing substantial healthcare burdens that necessitate effective therapeutic strategies. Ultrasound-guided high-intensity focused ultrasound emerges as a safe and effective treatment modality for uterine fibroids, with postoperative magnetic resonance imaging serving as a valuable tool for evaluating pelvic fascia integrity and surrounding tissue modifications. This review systematically examines the determinants influencing pelvic fascial dynamics and adjacent tissue alterations, while elucidating their clinical correlations with postoperative complications.

Keywords: uterine fibroids, High-Intensity Focused Ultrasound (HIFU), pelvic fascia edema, MRI, postoperative adverse reactions

1. Introduction

Uterine fibroids, are among the most common benign neoplasms affecting women of reproductive age, constitute hormone-dependent monoclonal tumors originating from the uterine myometrium, composed of smooth muscle cells, fibroblasts, and a substantial amount of fibrous extracellular matrix. Comprehensive research has established race as the foremost and most prevalent risk factor for the development of uterine fibroids. Advancing age, especially in premenopausal women and those over 40 years of age, emerges as another significant risk factor (Stewart EA, Cookson CL, Gandolfo RA & Schulze-Rath R., 2017). Moreover, personal and environmental factors, including smoking and excessive alcohol consumption, can also contribute to an increased risk of uterine fibroids. Scholarly literature suggests that stress may induce fluctuations in estrogen and progesterone levels, both of which play crucial roles in the pathogenesis of uterine fibroids (Donnez J & Dolmans MM., 2016). An elevation in these risk factors is associated with a heightened likelihood of the formation and progression of uterine fibroids (Yang Q, Ciebiera M, Bariani MV, et al., 2022). Clinically, patients may manifest symptoms such as menorrhagia, pelvic pain, infertility, recurrent spontaneous abortions, and preterm deliveries. Although a considerable proportion of fibroids remain asymptomatic, approximately 30% to 40% of patients experience a range of symptoms, the specific nature of which is contingent upon the location and size of the fibroids (Wallach EE & Vlahos NF., 2004).

Uterine fibroids constitute a significant health challenge for patients and impose a considerable burden on societal health and the economy. The diagnosis and clinical management of these fibroids necessitate tailored approaches, given their diverse types (Stewart EA, Lytle BL, Thomas L, et al., 2018). Currently, hysterectomy remains the primary treatment for uterine fibroids due to the lack of long-term or non-invasive alternatives (Liu L, Wang T & Lei B., 2022). Although surgical resection is effective, it carries risks and requires prolonged recovery. Uterine artery embolization (UAE) offers symptom relief but involves radiation and may affect ovarian function, limiting its use in women of reproductive age (Xu F, Deng L, Zhang L, Hu H & Shi Q., 2021). High-intensity focused ultrasound (HIFU), a non-invasive technique, induces coagulation necrosis through thermal ablation. Two systems exist: ultrasound-guided HIFU (USgHIFU) and magnetic resonance imaging-guided HIFU (MRgHIFU). Studies confirm the safety and efficacy of both in treating uterine fibroids. In clinical practice, physicians must consider patient-specific factors and preferences. USgHIFU is often preferred for its broad indications, convenience, cost-effectiveness, rapid recovery, and low complication risk, making it a suitable option for women wishing to preserve fertility (Bachu VS, Kedda J, Suk I, Green JJ & Tyler B., 2021; Lee JS, Hong GY, Lee KH, Song JH & Kim TE., 2019; Wang Y, Wang ZB & Xu YH., 2018).

Imaging techniques, particularly Magnetic Resonance Imaging (MRI), plays a pivotal role in the diagnosis and management of uterine fibroids, particularly in the realm of HIFU surgery, by furnishing accurate and detailed information that guides treatment planning, and the assessment of treatment outcomes. HIFU surgery, MRI assessment assumes paramount importance. Prior to the procedure, MRI provides comprehensive information on the number, size, and vascularization of fibroids, as well as their relationship with the endometrial cavity, serosal surface, and boundaries with the normal myometrium (Cheung VYT., 2018). This detailed anatomical and functional information is indispensable for precise treatment planning, ensuring that HIFU energy is targeted exclusively to the fibroids while sparing healthy uterine tissue. Moreover, MRI facilitates the identification of potential complications or risks, such as the proximity of fibroids to sensitive structures, thereby enhancing the safety of the procedure (Bachu VS, Kedda J, Suk I, Green JJ & Tyler B., 2021).

Consequently, MRI is routinely utilized for the pre- and post-operative assessment of uterine fibroids in patients undergoing HIFU surgery. Meanwhile, postoperative MRI often reveals changes in the signal intensity of other pelvic structures apart from the lesion, such as alterations in the sacral bone signal, soft tissue edema in the pelvic wall, and pelvic effusion.

2. Occurrence and Influencing Factors of Pelvic Fascia Edema on MRI After HIFU for Uterine Fibroids

Previous studies have demonstrated the safety of USgHIFU in the treatment of uterine fibroids. However, during the HIFU treatment process, the biological effects and physical effects of ultrasound may cause varying degrees of damage to tissues along the acoustic pathway or adjacent normal tissues (Liu Y, Zhang WW, He M, et al., 2018). Studies have revealed subtle changes in the corresponding pelvic floor structures after HIFU treatment, including pelvic fascia edema, alterations in sacral bone signals, and changes in pelvic effusion, among which pelvic fascia edema is relatively common (Zhang YJ, Xiao ZB, Lv FR, et al., 2020; Liu Y, Liu Y, Lv F, Zhong Y, Xiao Z & Lv F., 2022; Li D, Gong C, Bai J & Zhang L., 2020; Yin N, Hu L, Xiao ZB, et al., 2018).

2.1 Sites of Pelvic Fascia Edema Occurrence

The connective tissue composition of the female pelvis is complex, with the pelvic fascia constituting a continuous network of varying densities (Puntambekar S & Manchanda R., 2018). A portion of the pelvic fascia extends as a continuation of the visceral parietal fascia. The pelvic fasciae, oriented in different directions, interconnect and fuse, providing structural support to the pelvic vasculature and nervous system, and accommodating volume changes and relatively independent movements of the pelvic organs (Ercoli A, Delmas V, Fanfani F, et al., 2005). Following High-Intensity Focused Ultrasound (HIFU) ablation for uterine fibroids, the primary regions of pelvic fascia swelling are observed around the uterus, sacrum, bladder, and rectum. Notably, the anterior wall fascia and Waldeyer’s fascia are predictive sites for the occurrence of pelvic fascia swelling due to their perpendicular orientation relative to the acoustic pathway (Liu X, Dong X, Mu Y, Huang G, He J & Hu L., 2020). The locations of pelvic fascia edema are relatively consistent, manifesting as fascial thickening on MRI, with striated and reticular hyperintensity on T2-weighted images (T2WI), prominent hyperintensity on T2 fat-suppressed images, and linear hyperintensity on enhanced sequences. The primary cause of pelvic fascia swelling is the physical effects of ultrasound, such as reflection and refraction, at various biological tissue interfaces. These reflection interfaces may harbor energy deposition or ectopic micro-foci, leading to secondary focusing of ultrasound and subsequent thermal damage to tissues outside the target area (Liu Y, Liu Y, Lv F, Zhong Y, Xiao Z & Lv F., 2022).

Studies by Zhang Xuehua et al. observed fascial edema signals on post-HIFU MRI in nearly 70% of patients, and similar signal changes were found in research by the Liu Yuhang team (Liu Y, Liu Y, Lv F, Zhong Y, Xiao Z & Lv F., 2022; Zhang XH, Zhai SH, Dong GL, et al., 2017). These scholars’ analyses revealed that the occurrence of pelvic fascia edema is not correlated with patient age, fibroid number, fibroid volume, or fibroid type, but is correlated with the energy delivered by HIFU and the irradiation time. Furthermore, the Liu Yuhang team found that fibroids located on the anterior or posterior wall are more likely to cause pelvic floor fascia edema during HIFU treatment compared to those on the lateral wall, with the degree of pelvic floor fascia edema being relatively more severe after HIFU for posterior wall fibroids. This finding is consistent with the research by the Zhang’s team, indicating that fibroid location is also a factor influencing pelvic floor fascia edema (Liu Z, Gong C, Liu Y & Zhang L., 2018).

During clinical ultrasound ablation, several factors come into play. On one hand, when ablating fibroids located away from the abdominal wall, the transmission distance of the high-intensity focused ultrasound beam from the transducer to the fibroid is relatively large. Due to the physical properties of the ultrasound beam, mechanical effects, diffusion effects, and acoustic streaming effects occur at various interfaces along the surrounding tissues of the fibroid and the acoustic pathway (Yu T & Luo J., 2011), leading to energy loss. Consequently, the ultrasound energy and time required to ablate a unit volume of target tissue are positively correlated with the depth of the lesion. To ensure effective ablation of the fibroid, clinical practice involves using a higher total dose (TD) for fibroids located deep within the pelvis. According to the principles of HIFU ablation, a higher irradiation energy results in greater relative heat deposition within the tissue, making the soft tissues around the sacrococcygeal region more prone to swelling. On the other hand, as the distance from the ventral surface of the fibroid to the skin increases and the fibroid lies closer to the sacrum, the acoustic impedance difference at the interface between the fibroid and the bone becomes more significant. This reduces the attenuation of ultrasound energy in the posterior acoustic field, and due to the mechanical and diffusion effects of ultrasound, ectopic micro-foci can form within the surrounding soft tissues (Liu Y, Lv F, Liu Y, et al., 2024). Energy in the sacrococcygeal region is more likely to be deposited, causing swelling of the pelvic fascia around the sacrococcygeal bone, thereby increasing the risk of adverse effects (Yang MJ, Yu RQ, Chen WZ, Chen JY & Wang ZB., 2021).

2.2 Extent of Pelvic Fascia Swelling

Scholars have discovered that the incidence of pelvic fascia edema is correlated with the duration of ultrasound exposure. Furthermore, quantitative analysis of edema extent, based on the extent of fascial involvement, has demonstrated a positive correlation between the severity of pelvic floor fascia edema and the parameters of HIFU energy and irradiation time (Zhang YJ, Xiao ZB, Lv FR, et al., 2020). The extent of pelvic fascia edema is determined by the length of ultrasound exposure, and the therapeutic dose (TD) is also implicated in its occurrence. Previous research has established a link between TD and pelvic fascia edema, with the degree of fibroid enhancement influencing TD (Zhang XH, Zhai SH, Dong GL, et al., 2017). Studies have indicated that fibroids exhibiting marked enhancement are associated with a higher risk of developing pelvic fascia edema compared to those with other enhancement patterns. MRI contrast-enhanced imaging can be utilized to assess blood perfusion in heterogeneous uterine fibroids, with some studies suggesting that blood perfusion may be a pivotal parameter influencing temperature elevation and, consequently, ablation efficacy (Yang MJ, Yu RQ, Chen WZ, Chen JY & Wang ZB., 2021). In cases where the target uterine fibroid has a rich blood supply, the circulating blood can dissipate the heat deposited within the target tissue, facilitating heat loss and rendering ablation more difficult (Marinova M, Ghaei S, Recker F, et al., 2021). Research has shown that uterine fibroids with prominent enhancement and posterior location are more challenging to ablate, necessitating longer ultrasound exposure durations for HIFU ablation and resulting in elevated TD and Energy Efficiency Factor (EEF) values (Yang Z, Zhang Y, Zhang R, et al., 2014).

The TD is influenced by factors such as fibroid size, T2-weighted image (T2WI) characteristics, and enhancement degree, which indirectly suggests a synergistic effect between TD and ultrasound exposure time on the development of pelvic fascia edema (Yu SCH, Cheung ECW, Leung VYF & Fung LWY., 2019). Consequently, factors including fibroid location, contrast enhancement pattern, distance from the dorsal surface of the fibroid to the sacrum, and EEF play crucial roles in the occurrence of pelvic fascia edema following ultrasound-guided HIFU ablation. Furthermore, EEF, fibroid location, and enhancement pattern exhibit positive correlations with pelvic fascia edema, while the distance from the dorsal surface of the fibroid to the sacrum demonstrates a negative correlation with fibroid size. The pelvic fascia constitutes a continuous structure encompassing multiple fascial layers, and the pelvic floor fascia may play a pivotal role in chronic pelvic pain (Roch M, Gaudreault N, Cyr MP, Venne G, Bureau NJ & Morin M., 2021). From this perspective, comprehensive assessment of the entire pelvic fascia in research studies is essential for investigating postoperative adverse events.

3. Relationship Between Pelvic Fascia Edema on MRI and Postoperative Adverse Reactions After HIFU for Uterine Fibroid

The fundamental mechanism of High-Intensity Focused Ultrasound (HIFU) entails concentrating high-intensity acoustic waves onto a targeted tissue region. Within this region, the acoustic energy is converted into thermal energy, leading to a localized temperature increase, the generation of cavitation effects, and an elevated sensitivity of the surrounding tissues to heat (Liao L, Xu YH, Bai J, et al., 2023). Consequently, the tissue in this area undergoes thermal damage, manifesting as liquefactive necrosis, mechanical injury, or apoptosis (Keserci B & Duc NM., 2018). Owing to its distinct mechanism of action, HIFU can precisely destroy fibroid tissue while providing maximal protection to the adjacent normal tissues, thereby theoretically reducing the risks and complications associated with surgical interventions.

Ultrasound-guided HIFU ablation represents a technique whereby low-intensity ultrasound waves originating from outside the body are focused onto a specific target area within the body, creating a high-intensity ultrasound focus. This technology induces immediate coagulative necrosis of the tissue within the focal zone, without causing significant damage to the neighboring tissues. As such, conformal ablation treatment of the entire target tissue can be achieved through the precise control of the three-dimensional movement of the focal point. The excellent tissue penetration, energy deposition, and energy focusing capabilities of ultrasound establish the physical basis for its application as a therapeutic energy source in medicine. Given the unique physical properties of ultrasound and the inherent complexity of the human body and its diseases, the occurrence of complications remains a possibility.

3.1 Overview of Postoperative Adverse Reactions

Multiple studies have demonstrated that patients may experience varying degrees of adverse reactions after USgHIFU ablation for symptomatic uterine fibroids. Mild postoperative adverse reactions include abnormal vaginal discharge, lower abdominal pain, sacrococcygeal pain, paresthesia of the lower extremities, nausea and vomiting, skin blisters, fever, and hematuria. More severe adverse reactions include skin burns, leg pain, vaginal discharge or bleeding, urinary retention, acute cystitis, intrauterine infection, intestinal injury, acute renal failure, deep vein thrombosis, pubic symphysis injury, thrombocytopenia post-HIFU, sciatic nerve injury, and hydronephrosis (Yu T & Luo J., 2011). The incidence of postoperative adverse reactions may vary across studies due to differences in patient number, operation duration, and operators. Most studies agree that abnormal vaginal discharge is the most common adverse reaction after HIFU ablation for uterine fibroids (Fan HJ, Cun JP, Zhao W, et al., 2018). Yunchang Liu et al., through a long-term multicenter study, observed a comprehensive range of adverse reactions post-HIFU and concluded that skin burns are the most common complication, while intestinal injury is the most severe among the major adverse reactions following USgHIFU treatment for benign uterine diseases (Liu Y, Zhang WW, He M, et al., 2018; Fan HJ, Cun JP, Zhao W, et al., 2018; Zhang J, Yang C, Gong C, Zhou Y, Li C & Li F., 2022).

A multicenter, large-scale study conducted in 2015 retrospectively documented the incidence of adverse reactions during and after USgHIFU treatment for benign uterine diseases, following a standardized clinical protocol. The study classified and graded complications using the SIR classification system to assess the severity of postoperative adverse events. This study evaluated the efficacy and safety of USgHIFU in treating uterine fibroids, revealing that 10.6% of patients experienced adverse reactions postoperatively. According to the SIR classification, 94.1% of these reactions were categorized as Class A (Chen J, Chen W, Zhang L, et al., 2015). Early large-sample studies observed cases of acute renal insufficiency and intestinal perforation in some patients. Certain intestinal injuries may result from energy reflection due to calcification of uterine fibroids or local tissue ablation extending to the uterine outer wall (Yu T & Luo J., 2011). Nevertheless, recent studies have maintained a very low incidence of intestinal injury. The study emphasized that strict preoperative intestinal preparation, meticulous intraoperative intestinal protection, and controlled ablation scope are crucial to effectively mitigate the risk and incidence of intestinal injury (Chen J, Li Y, Wang Z, et al., 2018). Case reviews from large-sample studies found that patients with retroverted uteri and cervical uterine fibroids experienced bladder overfilling with saline during HIFU treatment. Postoperative edema led to enlargement of cervical fibroids, increasing the risk of ureteral compression and subsequent hydronephrosis (Fennessy FM, Tempany CM, McDannold NJ, et al., 2007). These patients recovered after three days of catheterization. Similarly, although the incidence of renal insufficiency is extremely low and its cause remains unclear, special attention should be given to potential underlying conditions that may contribute to renal insufficiency (Chen J, Chen W, Zhang L, et al., 2015). Additionally, renal function should be assessed following HIFU treatment. Intestinal injury is a potential complication that necessitates proactive prevention. Complications such as urinary retention or urinary tract infections resulting from intraoperative catheterization, and water-electrolyte imbalances due to dietary preparation or enemas, also warrant close monitoring and prevention.

Common complications associated with the acoustic pathway during ultrasound ablation treatment include skin toxicity and neurotoxicity, manifesting as skin blisters or sclerosis, and pain in the lower abdomen and extremities. Studies have identified factors such as abdominal wall scars, abdominal wall thickness, the distance from the ventral side of uterine fibroids to the skin, uterine fibroid volume, and body mass index (BMI) in the injury group as contributors to the occurrence of these thermal injuries (Yin N, Hu L, Xiao ZB, et al., 2018; Liu Y, Lv F, Liu Y, et al., 2024; Chendian T, Guohua H, Wang Z, et al., 2024). Furthermore, Peng et al. discovered that total energy is a significant factor contributing to thermal injury of abdominal wall structures, with a notable correlation between total energy deposition and thermal injury (Peng S, Zhang L, Hu L, et al., 2015). At the fat-muscle interface, the conversion of energy to thermal energy is most efficient, and fat tissue readily absorbs thermal energy, thereby increasing the risk of thermal injury (Baker KG, Robertson VJ & Duck FA., 2001). Neurotoxicity, often induced by sterile inflammatory stimulation, presents as sensory and motor dysfunction with an uncertain recovery period that correlates with the severity of neurotoxicity. In large-sample studies, some patients experienced sacral nerve irritation, with leg pain persisting for over two weeks post-HIFU treatment. The pain subsided after 1-3 months of non-steroidal anti-inflammatory drug therapy. One patient experienced persistent leg pain for 12 months, suggesting a possible concomitant sciatic nerve injury (Chen J, Chen W, Zhang L, et al., 2015).

Beyond the treatment area and the patient's clinical characteristics, which can influence the occurrence of postoperative adverse reactions, the amount of energy used during the ablation process is another factor. The more energy utilized, the greater the energy deposited in the surrounding tissues of the target area, thereby increasing the risk of thermal injury.

3.2 Correlation Between Pelvic Fascia Edema on MRI and Adverse Reactions

The pelvic fascia can be broadly categorized into the perirectal fascia and the fascia lining the four lateral walls of the pelvis. It constitutes a continuous network of connective tissue that envelops the pelvic structures, encompassing various fascias and spaces with the exception of the sacrococcygeal region. The posterior fascia, known as Waldeyer's fascia, overlays the pelvic plexus, where the inferior hypogastric nerve, pelvic splanchnic nerves, and sacral splanchnic nerves converge at the base of the rectum (Roch M, Gaudreault N, Cyr MP, Venne G, Bureau NJ & Morin M., 2021). Swelling of the fascia resulting from injury may irritate or compress the underlying nerves, giving rise to pain or sensory disturbances in the corresponding regions (Liu Y, Lv F, Liu Y, et al., 2024). Moreover, the surrounding fascia is implicated in the pathophysiology of pelvic floor disorders and plays a vital role in supporting and suspending the female pelvic floor structures.

Historically, few studies have comprehensively explored postoperative pelvic fascia edema. However, in recent years, researchers have increasingly recognized the significance of sacrococcygeal fascia edema, which has been found to be closely associated with postoperative sacrococcygeal pain (Zhang YJ, Xiao ZB, Lv FR, et al., 2020). It has been speculated that nerve damage following HIFU ablation in uterine fibroid patients may be linked to swelling of the pelvic fascia. During follow-up observations, adverse events, including sacrococcygeal pain and lower extremity sensory disturbances, abated within a week as the fascia swelling gradually diminished, indicating the potential for spontaneous recovery (Wang Y, Gong C, He M, et al., 2023). A study conducted by Zhang Yajiao et al. revealed a significant correlation between the location of pelvic fascia edema and the incidence of postoperative pain-related adverse events (Zhang YJ, Xiao ZB, Lv FR, et al., 2020). The statistical analysis indicated that patients with edema of the anterior wall fascia were at higher risk of experiencing lower abdominal pain. Conversely, the incidence of sacrococcygeal pain was lower among patients with anterior wall fascia edema but higher in those with posterior wall fascia edema and sacral injuries (Aq Z, Jy C, Zb X, R Z & J B., 2023).

Furthermore, some studies have demonstrated a notable correlation between sacrococcygeal pain and perirectal fascia edema, between the lateral position of fibroids and lateral fascia edema, and a higher incidence of lower extremity numbness and pain in patients with fibroids located on the right side compared to the left. Additionally, the incidence of sacrococcygeal and leg pain has been found to be significantly positively correlated with sacral injuries (Li D, Gong C, Bai J & Zhang L., 2020). Due to the high impedance interface and substantial ultrasound absorption coefficient of bone, a considerable amount of energy is deposited in the bony regions, leading to rapid heating and potential damage to the surface areas of the sacrum. Prolonged elevation of sacral temperature may result in thermal energy diffusing into the surrounding tissues, potentially damaging the piriformis muscle, its fascia, or the sacrococcygeal ventral ligaments and triggering inflammation.

Some authors posit that sacral pain is solely related to local tissue damage or inflammation without involving the sacral nerve, while leg pain is generally attributed to sacral nerve stimulation following HIFU (Li D, Gong C, Bai J & Zhang L., 2020). It is more plausible that sacral or leg pain is associated with the location of the signal-altered region.

4. Changes Adjacent to the Pelvic Fascia on MRI After HIFU for Uterine Fibroids

Changes in the pelvic cavity following HIFU treatment for uterine fibroids extend beyond fascial edema. Some scholars have observed that 16.2% of patients exhibit signals of pelvic effusion post-HIFU, with distinctive patterns in their distribution (Zhang XH, Zhai SH, Dong GL, et al., 2017). Zhang Xuehua's study revealed that, among patients with pelvic effusion, approximately 83% of the effusion is localized within the uterosacral recess, while 13% is found in both the uterosacral recess and the surrounding area of the uterus. This distribution is intrinsically linked to the nature of pelvic effusion and the anatomical configuration of the female pelvis. Pelvic effusion, being relatively free-floating, tends to accumulate in the lower regions of the pelvis, such as depressions and interstices. Furthermore, a small proportion of effusion can be detected beyond the uterosacral recess and the periuterine region, including the vicinity of the bladder and between the intestinal walls of the pelvis. However, to date, no studies have established a correlation between the location of effusion and factors such as fascial edema, fibroid characteristics, treatment parameters, or treatment outcomes. Existing research has merely analyzed the affected areas of effusion without delving into the quantification of effusion volume, highlighting a gap in this area of study.

Currently, a grading system exists for assessing pleural and peritoneal effusion, acknowledging that varying levels of effusion can induce different degrees of compressive symptoms in the body, some of which may be indicative of disease prognosis. The extent of pleural effusion, for instance, has a differential impact on lung function, with increasing effusion volume exacerbating the effects on pulmonary function (Mitrouska I, Klimathianaki M & Siafakas NM., 2004). Similarly, in patients with severe acute pancreatitis, studies have demonstrated a correlation between the volume of pleural effusion and the occurrence of complications (Bao ZG, Zhou Q, Zhao S, et al., 2024); a higher effusion volume is associated with an increased number of complications (Melo MFV & Bates JHT., 2013). Moreover, the volume of malignant ascites has been shown to be significantly correlated with the malignancy and prognosis of ovarian tumors (Shen-Gunther J & Mannel RS., 2002). Collectively, these studies underscore the influence of effusion volume on disease progression and patient condition. Quantitative grading of effusion can serve as a clinical tool to assess disease severity and gauge its impact on the function of adjacent organs.

Pelvic effusion, depending on its location, can deposit within the fascial spaces of the pelvis, exerting varying degrees of pressure on the pelvic fascia. The resultant fascial injury and swelling, coupled with the pressure exerted by the effusion, may irritate or compress the underlying nerves, leading to pain or sensory abnormalities in the corresponding regions (Liu Y, Liu Y, Lv F, Zhong Y, Xiao Z & Lv F., 2022). Whether this change bears any correlation with the onset or severity of pelvic fascial edema remains an unexplored avenue of research. Continued monitoring of pelvic effusion in patients undergoing HIFU treatment for fibroids, along with an investigation into the relationship between effusion volume and clinical treatment parameters, as well as its potential predictive role in the occurrence of adverse reactions, can provide valuable insights for clinical decision-making. This information can guide the selection and application of HIFU treatment parameters for uterine fibroids, with the aim of mitigating postoperative adverse reactions. Additionally, tailored postoperative care plans can be implemented based on individual patient MRI findings to shorten the duration of adverse reactions. This approach will facilitate the broader clinical adoption and application of HIFU, a non-invasive treatment modality.

5. Conclusion and Future Perspectives

HIFU, recognized as a safe and efficacious treatment for uterine fibroids, possesses distinct advantages. Nonetheless, the inevitable impact on adjacent tissues during the therapeutic process remains a consideration. Postoperative MRI can detect the presence of pelvic fascial edema, and a correlation has been established between the localization of this edema and pain-related adverse reactions. This correlation serves, to some extent, as a clinical foundation for guiding subsequent treatment and for adjusting the total energy and irradiation time employed in HIFU therapy. By implementing such adjustments, the objective is to minimize the extent and range of damage to non-target tissues and to reduce other side effects, thereby ameliorating patient discomfort and mitigating the overall impact on their health. However, research has yet to delve into the correlation and synergistic effects among changes in MR signals. The duration of tissue-related effects and their association with the onset of symptoms warrant further investigation and validation. Consequently, a thorough evaluation of overall tissue changes and the related influencing factors can assist clinicians in adopting more precise and tailored treatments, thereby attenuating the severity and duration of adverse reaction symptoms experienced by patients.

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