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Review

High-Intensity Focused Ultrasound (HIFU) Treatment for Prostate Cancer

Prostat Kanserinde Yüksek Yoğunluklu Odaklanmış Ultrason (HIFU) Tedavisi

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Keywords
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Absract
High-Intensity Focused Ultrasound (HIFU) represents an emerging minimally invasive treatment modality for prostate cancer. This technology employs focused ultrasound waves to ablate prostate tissue, offering a precise and targeted strategy for the management of localized prostate cancer. The present paper aims to deliver a comprehensive review of HIFU, encompassing its technology, advantages, risks, patient selection criteria, and post-treatment monitoring.

Anahtar Kelimeler
prostat kanseri
prostat görüntüleme
HIFU

Özet
Yüksek Yoğunluklu Odaklanmış Ultrason (HIFU), prostat kanseri için yeni ortaya çıkan minimal invaziv bir tedavi yöntemini temsil eder. Bu teknoloji, prostat dokusunu yok etmek için odaklanmış ultrason dalgaları kullanır ve lokalize prostat kanserinin yönetimi için kesin ve hedefe yönelik bir strateji sunar. Bu makale, teknolojisini, avantajlarını, risklerini, hasta seçim kriterlerini ve tedavi sonrası izlemeyi kapsayan HIFU'nun kapsamlı bir incelemesini sunmayı amaçlamaktadır.

High-Intensity Focused Ultrasound (HIFU) is an emerging, minimally invasive treatment option for prostate cancer. This technology utilizes focused ultrasound waves to ablate prostate tissue, providing a precise and targeted approach to managing localized prostate cancer. This paper aims to provide a comprehensive overview of HIFU, including its technology, benefits, risks, patient selection criteria, and post-treatment follow-up (1).

Prostate Cancer Prevalence and Pathology

Prevalence

Prostate cancer is one of the most common cancers among men worldwide. According to the American Cancer Society, about 1 in 9 men will be diagnosed with prostate cancer during their lifetime. It is the second leading cause of cancer death in men in the United States, with an estimated 248.530 new cases and 34.130 deaths in 2021 alone (1). The prevalence varies globally, with higher rates found in developed countries, partly due to increased screening and diagnostic practices.

Pathology

Localized Prostate Cancer

Localized prostate cancer is confined to the prostate gland and has not spread to nearby tissues or other parts of the body. It is typically classified into stages T1 and T2:

- Stage T1: The tumor is not palpable and is typically detected incidentally during a biopsy for elevated PSA levels.
- Stage T2: The tumor is palpable but confined to the prostate.

Multi-Focality

Prostate cancer often exhibits multifocality, indicating the presence of multiple distinct tumors within the prostate gland. Multifocal prostate cancer is observed in up to 85% of cases, and these foci can vary widely in terms of their grade and stage. This poses a challenge for localized treatments such as HIFU, which are intended to target specific areas of the prostate (2). The existence of multiple tumor foci can increase the risk of incomplete ablation and residual cancer.

Impact on Localized Treatment

The multifocal nature of prostate cancer requires a comprehensive assessment to detect all cancerous areas in the prostate. If not all foci are identified and treated, there is a risk of cancer recurrence. Therefore, accurate imaging and biopsy techniques are crucial to ensure that all cancerous areas are effectively targeted during HIFU treatment. Failure to address

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all tumor sites could result in suboptimal treatment outcomes and the potential need for additional therapies (3-5).

HIFU Technology

Mechanism of Action

HIFU works by directing focused ultrasound waves at the prostate tissue. The ultrasound waves pass through the surrounding tissues without causing damage and converge on the targeted region, where they generate high heat (around 80-100°C), resulting in coagulative necrosis of the cancerous cells. The precision of this technique enables the destruction of targeted tissues while sparing adjacent healthy systems (6).

Equipment and Procedure

The procedure typically involves the use of a transrectal probe that emits ultrasound waves. Patients are usually under general or spinal anesthesia to ensure immobility and comfort. Real-time imaging, often magnetic resonance imaging (MRI) or ultrasound, guides the probe to ensure precise targeting of the cancerous tissue (7). The duration of the procedure can vary but typically lasts between 1 to 3 hours, depending on the extent of the disease.

Multi-Parametric Prostate MRI and Fusion Biopsy

Multi-parametric prostate MRI (mpMRI) is an important tool in the analysis and management of prostate cancer. It combines anatomic imaging with advanced imaging techniques, including diffusion-weighted imaging (DWI), dynamic contrast-enhanced (DCE) imaging, and sometimes spectroscopy. MpMRI helps in accurately detecting and characterizing prostate lesions, evaluating their aggressiveness, and guiding biopsy and treatment planning. It provides a high level of detail that can distinguish between significant and insignificant prostate cancer lesions (8,9).

Fusion biopsy integrates mpMRI with real-time ultrasound imaging, providing a more precise and targeted approach to prostate biopsy. During the procedure, MRI images are overlaid onto live ultrasound images to guide the biopsy needle precisely to suspicious areas identified on the MRI. This method increases the detection rate of clinically significant prostate cancer compared to standard systematic biopsy (10).

Impact on HIFU Treatment

The use of mpMRI and fusion biopsy enhances the precision of HIFU treatment by providing detailed information about the location, size, and characteristics of prostate tumors. This allows for more accurate targeting during HIFU, minimizing damage to surrounding healthy tissues and improving treatment outcomes. Additionally, these imaging techniques help in selecting suitable candidates for HIFU, ensuring that the treatment is administered to patients with localized disease that can be effectively ablated (2).

Improving Outcomes with MRI

MpMRI improves the outcomes of HIFU treatment by providing:

- Enhanced Detection: MpMRI can detect clinically significant tumors that might be missed by traditional imaging and biopsy methods, ensuring that all cancerous areas are identified and targeted.
- Accurate Localization: By providing precise anatomical and functional information, mpMRI assists in the accurate localization of tumors, enabling targeted ablation and preservation of healthy tissue.
- Monitoring Response: Post-treatment mpMRI can be used to assess the response to HIFU, detecting any residual or recurrent disease early, which is essential for timely intervention (11).

Advantages of HIFU Treatment

Minimally Invasive

One of the primary benefits of HIFU is its minimally invasive nature. Unlike traditional surgical techniques, HIFU does not require any incisions, which reduces the risk of infection, bleeding, and postoperative pain (12).

Precision and Control

HIFU allows for precise targeting of cancerous tissues, minimizing damage to surrounding healthy tissues. This is particularly beneficial in preserving important functions such as urinary continence and erectile function.

Outpatient Procedure

HIFU is often performed as an outpatient procedure, allowing patients to return home on the same day. This reduces hospital stays and related healthcare expenses.

Repeatability

Since HIFU is a non-ionizing treatment, it may be repeated if necessary, providing a flexible option for recurrent prostate cancer (13,14).

Disadvantages of HIFU Treatment

Limited Long-Term Data

One of the primary drawbacks of HIFU is the limited long-term data available regarding its efficacy compared to established treatments like radical prostatectomy or radiation therapy. Most studies have short- to medium-term follow-ups, and long-term survival data is still being collected (15,16).

Side Effects

While HIFU is usually well-tolerated, it may cause side effects such as urinary tract infections, urinary retention, and, in some cases, erectile dysfunction. The severity and occurrence of these side effects can vary based on the individual patient's condition and the extent of the treatment. These side effects are reversible and curable (11,17).

Accessibility and Cost

HIFU isn't always widely available in all medical centers, and the cost of the system and procedure can be higher compared to other treatment modalities, potentially limiting its accessibility for some patients (18).

Patient Selection for HIFU Treatment

Criteria for Selection

Patient selection is crucial for the success of HIFU treatment. Ideal candidates typically include men with localized prostate cancer (T1-T2), a Gleason score of ≤7, and a prostate volume of ≤40 cc. However, all Gleason scores can be treated with HIFU. There are no contraindications in the literature (4,7). Patients with comorbid conditions that render them unsuitable for surgery may also be considered for HIFU (16,19).

Pre-Treatment Evaluation

A thorough pre-treatment assessment is vital to determine the suitability of HIFU. This consists of a detailed clinical history, physical examination, prostate-specific antigen (PSA) levels, multiparametric MRI, and, in some cases, a biopsy to confirm the diagnosis and stage of the cancer (20,21).

Post-Treatment Follow-Up

Immediate Post-Treatment Care

Following HIFU treatment, patients are usually monitored for several hours before being discharged. They might also experience mild discomfort, urinary frequency, or hematuria, which typically resolves within a few days. A urinary catheter is often inserted temporarily to aid with urination.

Long-Term Monitoring

Long-term follow-up includes regular PSA testing, typically every three to six months during the first year and annually thereafter. A significant increase in PSA levels may indicate recurrence, necessitating further diagnostic evaluation and potential retreatment (22,23).

Imaging Studies

Periodic imaging studies, such as MRI or ultrasound, can be conducted to assess the prostate's condition and identify any remaining or recurring illness. These follow-ups are crucial for ensuring the early detection of potential complications or recurrence (24).

Managing Side Effects

Management of side effects is an indispensable part of post-treatment care. Patients experiencing urinary symptoms or erectile dysfunction may benefit from medications, pelvic floor exercises, or other supportive therapeutic procedures. Continuous monitoring and prompt control of any adverse effects are essential for maintaining quality of life (25).

Conclusion

HIFU represents a promising treatment modality for localized prostate cancer, offering a minimally invasive option with unique precision capabilities. While it offers several benefits, such as reduced recovery time and repeatability, it also has limitations, including the need for further long-term efficacy data and potential side effects. The integration of mpMRI and fusion biopsy enhances the precision and effectiveness of HIFU treatment. Careful patient selection and thorough post-treatment follow-up are essential for optimizing outcomes. As the technology advances and more data becomes available, HIFU may become a more widely adopted treatment option for prostate cancer.

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