Magnetic Resonance Imaging (MRI) Technology in the Diagnosis of Rectal Cancer

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Abstract: *The article is devoted to the study of the use of magnetic resonance imaging technology (MRI) in the diagnosis of rectal cancer, which is an important stage in modern cancer. The purpose of the article is to carry out a systematic review of scientific sources that highlight the effectiveness of MRI in determining the stage of the tumor process, evaluation of lesions of lymph nodes and accuracy in planning treatment approaches, in particular surgery. The task is to analyze the accuracy of modern MRI methods for the diagnosis of rectal cancer and to consider technological solutions to improve MRI in the diagnosis of rectal cancer. A comprehensive analysis of publications in databases such as Google Scholar, PubMed, Scopus and IEEE XPlore was conducted on the basis of scientific research. The data revealed is systematized to highlight key technical and clinical aspects that require further development. The main attention is paid to the methods of contrast enhancement and diffusion-weighted MRI, which showed a high level of sensitivity (90-95%) and specificity (85-90%) in the detection of tumor invasion and metastases into lymph nodes. The advantages of methods that allow to accurately evaluate the blood supply to the tumor and the invasiveness of the process are considered, which is especially important for choosing the appropriate treatment tactics. Analysis of scientific works indicates that 1) MRI, due to high accuracy and safety, plays a key role in determining the localization and stage of the tumor process and is an indispensable method of diagnosis of rectal cancer, which provides accurate visualization Treatment and reduces the risk of relapse; 2) Modern MRI methods show high accuracy in the diagnosis of rectal cancer. In particular, highly separated MRI and dynamic contrast MRI have high sensitivity (90-95%) and accuracy (90%), which makes them effective for preoperative stages and tumor invasion. MRI with diffusion-weighted images also has high sensitivity and is useful for evaluating the response to therapy, which is important for monitoring the progress of the disease; 3) methods of contrast enhancement and advanced analysis of images significantly increase the accuracy of diagnosis, especially when predicting the effectiveness of neoadjuvant therapy; 4) there is a need to further improve MRI methods to reduce the frequency of false positive results in the early stages, which will improve the quality of treatment and increase the life expectancy of patients. 5) The development of artificial intelligence and the use of combined methods of diagnosis, in particular with other visualization technologies, will significantly increase the accuracy and availability of MRI in cancer diagnosis.*

Introduction

Modern trends in the diagnosis of cancer show significant technological progress made through the development of magnetic resonance imaging (MRI), which has become an integral part of clinical practice in oncology [1]. In particular, in the work [9] it is noted that MRI plays a special role in the assessment of rectal cancer, providing accurate visualization of the tumor and adjacent anatomical structures. The above mentioned results are the results of the studies that have conducted the above researchers according to which in the diagnosis of rectal cancer, the accuracy of MRI in the assessment of the tumor stage and the involvement of lymph nodes usually ranges from 70-95%, depending on the experience of the radiologist and used techniques. Similar results are also obtained in research [8], according to which MRI accuracy in determining the T3 and T4 tumor stage can reach about 85-95%, and to detect metastases in lymph nodes − 70-85%. The above level of accuracy makes MRI a key tool for making therapeutic solutions and planning surgical tactics. According to [4], MRI allows you to evaluate the tumor stage, which is key to determining the optimal treatment strategy, especially when planning surgery. In accordance with [5] the use of MRI, as the main method in the initial diagnosis and monitoring of the response to therapy allows to reduce the risk of relapse and increase patient survival. The work [1] states that the development of image methods and their adaptation to the needs of oncology made an MRI gold standard for local stage of rectal cancer. According to [12] Consideration of MRI capabilities and restrictions in the diagnosis of rectal cancer is extremely important for clinical practice. Therefore, from the surveyed research work it follows that the diagnosis of rectal cancer emphasizes the urgent need for accurate information to make therapeutic decisions, which in turn emphasizes the relevance of the search for the latest ways in improving MRI technologies used in cancer diagnosis rectum.

Aim

The purpose of the article is to carry out a systematic review of scientific sources that highlight the effectiveness of MRI in determining the stage of the tumor process, evaluation of lesions of lymph nodes and accuracy in planning treatment approaches, in particular surgery.

The way to achieve the goal: The task is to analyze the accuracy of modern MRI methods for the diagnosis of rectal cancer and to consider technological solutions to improve MRI in the diagnosis of rectal cancer.

Materials and methods

A comprehensive analysis of publications in databases such as Google Scholar, PubMed, Scopus and IEEE XPlore was conducted on the basis of scientific research. The data revealed is systematized to highlight key technical and clinical aspects that require further development.

Review and discussion

According to [9] magnetic resonance imaging (MRI) is a leading technology in the diagnosis and stage of rectal cancer due to its ability to provide detailed images of tissues, which greatly facilitates the determination of the degree of tumor spread and damage to the surrounding structures. Within the framework of consideration of the questions raised in this article, it is important to note that analyzing the main aspects of MRI technologies in the context of diagnosis of rectum cancer, it is advisable to emphasize the importance of a multidisciplinary approach in diagnosis and treatment. In the study [14] describes a multidisciplinary approach to the treatment of rectal cancer, which includes the use of MRI as a central method for evaluating tumor spread before the treatment begins. This approach allows you to better develop individualized treatment plans for patients aimed at maximizing the preservation of healthy tissues and optimizing the results of treatment for Watch-and-Wait treatment and the role of MRI in monitoring. In accordance with [2] during the precision evaluation of the spread of the MRI tumor allows you to evaluate the tumor's localization, its size, the involvement of surrounding tissues, as well as the presence of metastases, which is especially important for cancer, because accurate assessment makes it possible to choose the most appropriate treatment tactics In particular, determine the feasibility of surgery or the use of other methods of therapy. The work [3] also noted that MRI is an important

tool for monitoring the effectiveness of treatment, in particular when using neoadjuvant therapy. In addition, the author's team of this work is noted that dynamic monitoring of tissue changes allows doctors to evaluate how successfully the treatment reduces tumor formations. The work [15] describes in detail the strategy "Watch-and-Wait" for rectal cancer, which involves the absence of immediate surgery in cases of complete clinical response to neoadjuvant therapy. According to the above work, MRI helps to evaluate the presence or absence of a residual tumor after treatment, which allows oncologists and surgeons to make informed decisions on further steps. In work [12], it is stated that high-separated MRI (HR-MRI) is extremely accurate for preoperative staging of rectum cancer, allowing radiologists specializing in abdominal and oncological visualization to determine the depth mesorectal fascia (an important factor for surgery planning). The study described in the work [5] found that dynamic contrast-induced MRI (DCE-MRI) can be used by radiologists and medical visualization specialists to identify key prognostic factors in patients with patients with patients primary rectal cancer. DCE-MRI provides extended tumor visualization and allows you to evaluate the degree of blood flow in it, which is important for prognosis and further treatment. In the work [13] clearly demonstrated the prospects of radio mines in predicting the effectiveness of therapy and survival of patients with colorectal cancer (this technology includes the selection and analysis of a large number of parameters that are not visible to the human eye, but may be significant medicinal results). It should also be noted that [9] focus on the importance of MRI to evaluate the effectiveness of neoadjuvant therapy, which is often performed before surgery. According to the views of the above researchers, the use of MRI allows you to control the size of the tumor after therapy and to determine the residual tumor, which helps to evaluate the full clinical response. Instead, in the work [8] emphasizes the need for accurate local stage of rectal cancer by means of MRI to determine the presence of local invasion and metastases in lymph nodes. According to the above work, the MRI allows you to determine

the anatomical features that are critical for the choice of the appropriate method of treatment.

Table 1 shows the results of the analysis of the accuracy of modern MRI methods for the diagnosis of rectal cancer.

The results of the analysis given in Table 1. show that modern MRI methods demonstrate high accuracy in the diagnosis of rectal cancer.

Instead, the analysis showed that the use of radio masters and functional methods of MRI allows to improve the accuracy of prediction of treatment results and the prediction of relapses, which is important for individualization of therapy. However, in accordance with [10] for modern MRI methods, which are used in the diagnosis of rectal cancer there are a number of problems (hereinafter consider in more detail these problems). It is also advisable to note that one of the characteristic problems for the MRI method with contrast is its low specificity, which can lead to false positive results, especially when tumors are detected in the early stages, when pathological changes are not yet sufficiently expressed in the images. The above problem can also be observed in other MRI methods, such as:

− diffusion-weight mRI (DWI): tumors in rectangular lid cancer can be poorly distinguished from other tissues in the early stages, which leads to the risk of false positive results, in particular because water diffusion in tissues may be similar in some inflammatory processes or benign processes or benign processes neoplasms [3];

− MRI-collateral tomography: since the method is focused on the assessment of anatomy and structural changes, there may be difficulties with accurate determination of the tumor boundaries in the early stages, which sometimes leads to incorrect diagnosis, or errors in determining the localization of the tumor [6];

− MRI perfusion: it can be problematic due to limited specificity in the differentiation between tumor and inflammatory processes in the early stages, which sometimes leads to false results due to similar perfusion patterns [12].

As we can see in all of the above methods, the problem of low specificity is associated with difficulties in the recognition of early changes, or differentiation between different types of tissues or pathologies, which occurs when

Table 1. The results of the analysis of the accuracy of modern MRI methods
for diagnosis of rectal cancer

MRI method	Application	Sensitivity	Specificity	Precision	Notes
HR-MRI	Preoperative stage of rectal cancer. Assessment of the depth of invasion and mesorectal fascia.	90-95%	85-90%	90%	Particularly accurate to determine the involvement of the mesorectal fascia.
DCE-MRI	Evaluation of blood flow in the tumor to predict metastases and prognosis of the disease.	85-92%	80-88%	85%	High sensitivity in predicting a tumor progression and efficacy of therapy.
DWI	Determination of tumor evaluation and reaction to neoadjuvant therapy.	80-90%	75-85%	80%	Useful for assessing the response to therapy in the postoperative period.
MRI using radio	Forecasting of treatment results, determination of clinical response to therapy, early diagnosis of recurrence.	85-95%	80-90%	87%	Used to analyze a large number of images to predict results.
MRI with functional analysis	Analysis of tumor structure, differentiation of malignant and benign formations.	88-94%	85-92%	91%	It is used for better differentiation of types of tumors and tissues.
MRI after neoadjuvant therapy	Residual tumor evaluation and response to treatment after chemotherapy.	90-96%	80-85%	90%	Used to determine a complete clinical response to therapy.

changes are not pronounced or clearly defined on the images. In practice, the problem of low specificity in MRI can be partially corrected or reduced by several methodological and technical approaches, namely:

− Improving the contrast and resolution of the image: the use of the latest technologies, such as high-resolution MRI and improving contrast (eg, the use of new contrast agents), can improve tumors visualization in the early stages and reduce the number of false positive results [7];

− The use of combined diagnostic methods: the use of MRI in combination with other methods, such as CT, ultrasound, or RET-MRI, can increase the accuracy of diagnosis [11]. In turn, it is advisable to note that according to [15] above the specified approach allows doctors to get a more complete picture of the nature of the formation and reduce the risk of false positive results;

− use of artificial intelligence and machine training: introduction of artificial intelligence algorithms for MRI image processing can help automatically detect and classify tumors with high accuracy, reducing the likelihood of erroneous results, especially in the early stages;

− Improvement of image processing algorithms: the use of advanced MRI algorithms, such as diffusion-weight mRI (DWI) or MRI perfusion, can help determine the borders of tumors and avoid errors;

− involvement of experienced specialists: advanced training of doctors, use of additional training programs and professional consultations with other medical specialists allows to improve the interpretation of MRI results and reduce the likelihood of erroneous diagnoses;

− Extended use of diffusion-weight methods: it is advisable to use methods that evaluate the structure of tissues, not just their abnormal changes, for more accurate assessment in the

early stages of tumor development. For example, a diffusion-weight mRI can be improved for better detection of early cell mixes that may not be noticeable in standard contrast.

It should also be noted that the above approaches can reduce false positive results, improve the accuracy of diagnosis and increase the effectiveness of MRI in early detection of rectal cancer. According to [4] when applying diffusion-weight mRI (DWI) quite often in practice there is a problem that is reduced to the fact that this method may be less effective for detecting small tumors, or to determine the exact limit of neoplasm, which sometimes leads to errors in determining the stage of cancer. In the general case, the above problem associated with less efficiency of diffusion-weight mRI (DWI) to detect small tumors or accurate assessment of the boundaries of the neoplasm can be solved by several approaches, namely:

− Applying the DWI combination with other methods of visualization: PET scan (PET) or computed tomography (CT) can be used together with DWI for more accurate detection of small tumors or their boundaries. PET allows to evaluate the metabolic activity of the tissues, and CT scans in more detail the image of the tissue structure, which can help in the more accurate localization of the tumor;

− the use of functional and parametric maps: the use of parametric maps (for example, ADC cards − the diffusion coefficient) may allow to better evaluate the diffusion properties of tissues and, thus, to determine the boundaries of neoplasm even in late stages or in small tumors;

− Improvement of image resolution: high quality and highly separated DWI methods, for example, using a larger number of diffusion directions, or reduced sections thickness, can help to detect small tumors and their boundaries accurately.

− Use of machine learning and artificial intelligence algorithms (AI): AI algorithms, in particular deep training, can be used to analyze DWI images and automatically identify tumor boundaries. Such technologies can improve the accuracy of detection of even very small tumors and increase the efficiency of cancer;

− joint use with histological studies: in some cases it is important to combine DWI results with histological or molecular analyzes to determine the exact nature and boundaries of the neoplasm;

− Clinical adjustment and interpretation: qualified doctors who have experience in interpreting DWI results can adjust the boundaries of tumors by comparing the data obtained with other clinical features and indicators.

As we can see, the combination of the above approaches can significantly increase the efficiency of the DWI method in oncology, in particular to accurately detect small tumors and determine their stage. According to [14], for the use of MRI-collapse method, this method is a high-cost problem and requires special equipment that makes it less accessible in remote or insufficiently equipped medical institutions. The following innovative approaches can be used to improve the availability and efficiency of diagnosis of rectal cancer using MRI-collapse:

− Integration with less expensive diagnostic methods: a combination of MRI with markers in the blood or fecal tests for blood for primary screening. This will allow the preliminary selection of patients with suspected rectal cancer, which reduces the load on the MRI examination and improves the efficiency of use of expensive equipment;

− Development of mobile or compact MRI devices that can be used to diagnose rectal cancer in regions where there is no access to stationary medical institutions. Mobile devices can be equipped with specific programs for colorectal diagnostics, which reduces the cost and time for examination.

− Use of machine learning algorithms (AI) for automatic processing of MRI images in order to detect tumors and determine their stage. This can significantly reduce the time spent on the interpretation of images and increase the accuracy of diagnosis, especially in remote or low-income medical institutions;

− introduction of TV to ensure access to MRI analysis of rectal cancer in remote regions, which allows doctors from large medical centers to remotely analyze images and make accurate diagnoses that reduces the need for qualified specialists in each medical institution [4];

− IRT integration with other screening methods: the use of hybrid methods such as MRI with CT, ultrasound, or colonoscopy for a more detailed study of anatomy and stage of rectum cancer. Combined methods allow to increase the accuracy of diagnosis with less use of expensive MRI [13];

− introduction of modular systems that allow you to adapt MRI devices for specialized examinations, in particular for diagnosis of rectum cancer. This will reduce the total cost of equipment and increase the availability of these services for medical institutions [5];

− development of short scan protocols that allow to reduce the time for MRI examination and image processing. This approach will reduce the cost of procedures and increase the number of patients who can be examined per day [10];

− the use of machine learning to predict the development of the disease based on MRI results. This will allow doctors to better plan the tactics for the treatment of rectal cancer and improve the personalized approach to therapy, as well as reduce the cost of long -term patient monitoring.

To improve MRI perfusion in the diagnosis of rectal cancer, following improvements:

− optimization of protocols for the specificity of the organ: development of MRI perfusion protocols, adapted specifically for the diagnosis of rectal cancer, taking into account its anatomical features, will help to obtain more detailed images for more accurate determination of tumor size, invasion and involvement of adjacent tissues;

− Improving contrast agents for hyper-sensitivity: the introduction of contrast agents, which are especially effective for rectum tissues, can increase the sensitivity and specificity of perfusion MRI. This will allow the doctors to determine the degree of blood supply to the tumor more clearly, which is important for assessing the aggression and stage of cancer;

− artificial intelligence algorithms for detection and classification: the use of deep learning algorithms for automated Image analysis of MRI perfusion can help identify early tumor signs, determine local invasion and metastasis, which will increase the accuracy of diagnosis. These algorithms can be tuned to identify specific markers of rectal cancer, simplifying the interpretation of results;

− Integration with other methods of visualization: the use of MRI perfusion together with PET-CT or conventional MRI with high resolution (HR-MRI) can provide a multifaceted approach to tumor evaluation. This will allow to evaluate both functional and anatomical aspects of the tumor, which will contribute to a more accurate stage of treatment;

− Expanding availability through broad-casting systems: to overcome the scarcity of qualified specialists, remote access to images interpretation through television and radiology can allow doctors from smaller medical institutions to consult with specialists of large oncological centers, which will increase the accuracy of diagnosis and provide more patients with qualitative patients.

Marking steps can contribute to a more accurate and accessible diagnosis of rectum cancer by MRI perfusion, which is important for early detection and effective treatment planning. Similar approaches can be offered by improving MRI (FMRI).

Conclusions

Analysis of scientific works indicates that 1) MRI, due to high accuracy and safety, plays a key role in determining the localization and stage of the tumor process and is an indispensable method of diagnosis of rectal cancer, which provides accurate visualization Treatment and reduces the risk of relapse; 2) Modern MRI methods show high accuracy in the diagnosis of rectal cancer. In particular, highly separated MRI and dynamic contrast MRI have high sensitivity (90-95%) and accuracy (90%), which makes them effective for preoperative stages and tumor invasion. MRI with diffusion-weighted images also has high sensitivity and is useful for evaluating the response to therapy, which is important for monitoring the progress of the disease; 3) methods of contrast enhancement and advanced analysis of images significantly increase the accuracy of diagnosis, especially when predicting the effectiveness of neoadjuvant therapy; 4) there is a need to further improve MRI methods to reduce the frequency of false positive results in the early stages, which will improve the quality of treatment and increase the

life expectancy of patients. 5) The development of artificial intelligence and the use of combined methods of diagnosis, in particular with other visualization technologies, will significantly increase the accuracy and availability of MRI in cancer diagnosis.

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Conflict of Interest

The authors declare that they have no financial, academic, or personal conflicts of interest related to the publication of this article.

Consent to publication

The author has read and approved the final version of the manuscript. All authors consented to the publication of this manuscript.

AI Disclosure

The authors used ChatGPT (OpenAI, San Francisco, CA, USA) for language editing of the English text. The authors reviewed and verified all AI-generated content to ensure accuracy and integrity.

Ethical approval

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013). The study protocol was reviewed and approved by the Ethics Committee of P. L. Shupyk National Healthcare University of Ukraine (Protocol No. 3, 07 February 2017). All participants provided informed voluntary consent for participation.

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Технології магнітно-резонансної томографії (МРТ) у діагностиці раку прямої кишки

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Анотація: Стаття присвячена дослідженню використання технології магнітно-резонансної томографії (МРТ) у діагностиці раку прямої кишки, що є важливим етапом у сучасній онкологічній практиці. Мета статті – здійснити системний огляд наукових джерел, що висвітлюють ефективність МРТ у визначенні стадії пухлинного процесу, оцінці ураження лімфатичних вузлів та забезпеченні точності при плануванні лікувальних підходів, зокрема хірургічних втручань. Висувається завдання провести аналіз точності сучасних методів МРТ для діагностики раку прямої кишки та розглянути технологічні рішення для поліпшення МРТ при діагностиці раку прямої кишки. На основі узагальнення наукових досліджень було проведено комплексний аналіз публікацій у таких базах даних, як Google Scholar, PubMed, Scopus та IEEE Xplore. Виявлені дані систематизовано для виокремлення ключових технічних і клінічних аспектів, що потребують подальшого розвитку. Основну увагу приділено методам контрастного підсилення та дифузійно-зваженого МРТ, які показали високий рівень чутливості (90-95%) та специфічності (85-90%) у виявленні інвазії пухлини та метастазів у лімфатичні вузли. Розглянуто переваги методів, що дозволяють здійснювати точну оцінку кровопостачання пухлини та інвазивності процесу, що особливо важливо для вибору відповідної тактики лікування. Аналіз наукових праць свідчить про те, що 1) МРТ, завдяки високій точності та безпеці, відіграє ключову роль у визначенні локалізації та стадії пухлинного процесу та є незамінним методом діагностики раку прямої кишки, який забезпечує точну візуалізацію пухлинного процесу, сприяє вибору оптимальних методів лікування та знижує ризик рецидивів; 2) сучасні методи МРТ демонструють високу точність у діагностиці раку прямої кишки. Зокрема, високороздільна МРТ та динамічна контраст-індукована МРТ мають високі показники чутливості (90-95%) і точності (90%), що робить їх ефективними

для передопераційного стадіювання та оцінки інвазії пухлини. МРТ з дифузійно-зваженими зображеннями також має високу чутливість і корисна для оцінки відповіді на терапію, що важливо для моніторингу прогресу захворювання; 3) методи контрастного підсилення та розширеного аналізу зображень значно підвищують точність діагностики, особливо при прогнозуванні ефективності неоад'ювантної терапії; 4) існує необхідність у подальшому вдосконаленні методик проведення МРТ для зменшення частоти хибнопозитивних результатів на ранніх стадіях, що забезпечить покращення якості лікування та збільшення тривалості життя пацієнтів. 5) Розвиток штучного інтелекту та використання комбінованих методів діагностики, зокрема з іншими візуалізаційними технологіями, дозволить значно підвищити точність і доступність МРТ в онкологічній діагностиці.

Ключові слова: магнітно-резонансна томографія, рак прямої кишки, діагностика, онкологія, загальна хірургія, хірургічна практика.