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НАУЧНЫЙ ОБЗОР

THE ROLE OF MULTIPARAMETRIC MRI IN DIAGNOSING BREAST CANCER IN PATIENTS WITH DENSE BREAST TISSUE

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This article presents a comprehensive review of the critical role of magnetic resonance imaging (MRI) in diagnosing breast cancer, particularly in patients with dense breast tissue. The review underscores the limitations of standard mammograms in detecting malignancies obscured by dense tissue, emphasizing the diagnostic advantages of multiparametric MRI. By synthesizing findings from recent literature and evaluating the diagnostic efficacy of MRI compared to conventional mammography, this review aims to establish a practical approach that integrates both modalities to enhance diagnostic accuracy. Additionally, it highlights the importance of interdisciplinary collaboration across various fields to improve the precision of breast cancer detection.

The review analyzes a range of research data, focusing on studies that compare MRI to conventional mammography. It includes findings relevant to dense breast tissue, diagnostic accuracy and specific patient populations, recognizing trends and outcomes associated with MRI utilization. By assessing existing mammographic data and exploring the diagnostic capabilities of MRI techniques, the study proposes a comprehensive framework to guide clinical practice.

In conclusion, multiparametric MRI offers significant advantages for diagnosing breast cancer in patients with dense breast tissue, where conventional methods often fall short. The integration of MRI with standard mammography facilitates a more effective approach to early detection and treatment planning. Future research should focus on refining these techniques and enhancing their clinical applications to improve patient outcomes.

Keywords: magnetic resonance imaging, breast cancer, dense breast tissue, diagnosis, mammography.

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RUSSIAN ELECTRONIC JOURNAL OF RADIOLOGY

РОЛЬ МУЛЬТИПАРАМЕТРИЧЕСКОЙ МРТ В ДИАГНОСТИКЕ РАКА МОЛОЧНОЙ ЖЕЛЕЗЫ У ПАЦИЕНТОК С ПЛОТНОЙ ЖЕЛЕЗИСТОЙ ТКАНЬЮ

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В статье представлен анализ роли магнитно-резонансной томографии (МРТ) в диагностике рака молочной железы, особенно у пациенток с высокой плотностью ткани молочной железы. Рассматриваются ограничения стандартной маммографии в выявлении злокачественных новообразований, скрытых плотной тканью, с акцентом на диагностические преимущества мультипараметрической МРТ. Синтезируя данные из современной литературы и оценивая диагностическую эффективность МРТ в сравнении с традиционной маммографией, авторы ставят целью разработку практического подхода, который объединяет оба метода для повышения точности диагностики. Кроме того, подчеркивается важность междисциплинарного сотрудничества для повышения точности выявления рака молочной железы.

Статья включает анализ данных из различных исследований, посвящённых сравнению МРТ и стандартной маммографии. Рассматриваются работы, имеющие отношение к плотной ткани молочной железы, диагностической точности и отдельным группам пациентов, а также выявляются тенденции и результаты, связанные с использованием МРТ. Оценка существующих данных маммографии и изучение диагностического потенциала методик МРТ позволяет предложить комплексный подход к клинической практике.

В заключение отмечается, что мультипараметрическая МРТ обладает значительными преимуществами в диагностике рака молочной железы у пациенток с плотной тканью, где традиционные методы часто оказываются недостаточными. Интеграция МРТ со стандартной маммографией способствует более эффективному подходу к раннему выявлению и планированию лечения. В будущем исследования должны быть направлены на оптимизацию этих методов и их клинического применения для улучшения результатов лечения пациентов.

Ключевые слова: магнитно-резонансная томография, рак молочной железы, плотная ткань молочной железы, диагностика, маммография.

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Breast cancer remains one of the most prevalent cancers affecting women worldwide, with over 2.3 million new cases diagnosed in 2020 alone. This statistic underscores the critical importance of effective screening and early detection strategies. Among the various factors influencing the sensitivity of mammography, breast density is particularly significant, impacting the likelihood of accurate cancer diagnosis. Dense breast tissue is prevalent in approximately 40-50% of women undergoing screening mammography, particularly among younger women, and tends to diminish with age as breast composition changes.

Mammography is often considered as the gold standard for breast cancer screening; however, it may miss up to 30-50% of cancers in women with dense breasts, compared to only 10-20% in those with non-dense tissue. This disparity highlights the increased risk of missed diagnoses, with women possessing dense breast tissue facing a four to six times greater chance of undetected malignancies. Furthermore, the cancers that are identified in this demographic are frequently larger and diagnosed at more advanced stages than those in women with lower breast density [1, 2, 3]. The higher incidence of interval cancers (tumors found between routine

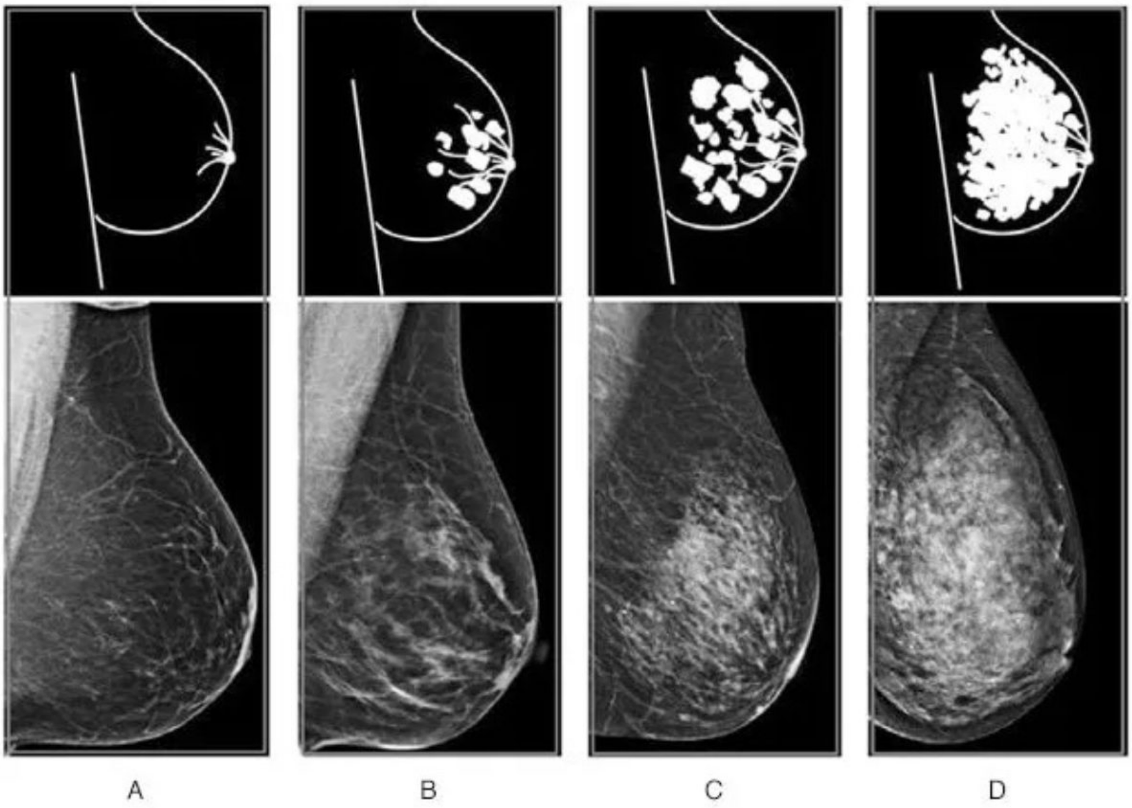

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Fig. 1 (Рис. 1)

Fig. 1. Scheme and mammograms: comparison of breast density categories according to the BI-RADS scale on mammographic images ©MAYO FOUNDATION.

The BI-RADS scale identifies four levels of breast density:

- A: almost entirely fatty breast tissue.
- B: scattered areas of fibroglandular density.
- C: heterogeneously dense breast tissue, which may obscure small masses.
- D: extremely dense breast tissue, significantly increasing the likelihood of missed diagnoses [5].

Рис. 1. Схема и маммограммы: сравнение категорий плотности молочной железы по шкале BI-RADS на маммографических снимках (©MAYO FOUNDATION).

Шкала BI-RADS выделяет четыре категории плотности молочной железы:

- A: молочная железа почти полностью состоит из жировой ткани.
- B: молочная железа преимущественно состоит из жировой ткани с наличием небольших участков повышения плотности.
- C: ткань молочной железы гетерогенная, состоит из значительного количества фиброзно-железистой и жировой ткани.
- D: молочная железа практически полностью состоит из фиброзно-железистой ткани [5].

screenings) emphasizes the urgent need for supplementary screening methods.

The link between dense breast tissue and breast cancer risk has led to growing interest in supplemental imaging techniques, particularly magnetic resonance imaging (MRI). MRI has been shown to possess superior sensitivity in detecting breast cancer, especially in dense tissues. Its ability to produce high-resolution images without the interference of overlapping tissues makes it an invaluable tool in early detection. Additionally, recent studies indicate that incorporating MRI into the screening regimen for women with dense breasts may significantly reduce the rate of missed diagnoses, ultimately improving survival outcomes.

However, despite the advantages of MRI, its integration into standard breast cancer screening protocols faces challenges. The higher cost of MRI, along with the need for specialized equipment and trained personnel, presents barriers to widespread adoption. Moreover, the psychological impact of false-positive results from MRI screening can lead to increased anxiety and unnecessary interventions, complicating the decision-making process for both patients and healthcare providers [4].

This article aims to explore the multifaceted role of MRI in diagnosing breast cancer in women with dense breast tissue. It will examine the current understanding of breast density and its implications for cancer risk, the advantages of MRI as a supplemental screening tool, economic evaluations of MRI utilization, and the challenges faced in integrating MRI into standard breast cancer screening protocols. Through this comprehensive examination, the review seeks to underscore the critical need for tailored screening approaches that effectively address the unique challenges posed by dense breast tissue in the ongoing fight against breast cancer.

Understanding Breast Density.

Breast density refers to the proportion of fibroglandular tissue to fatty tissue in the breast.

This composition is categorized into four distinct levels by the American College of Radiology using the Breast Imaging Reporting and Data System (BI-RADS):

Fatty Breast Tissue: predominantly fatty tissue results in dark or lucent mammograms, facilitating the visualization of abnormalities. Women classified under this category are associated with a lower risk of developing breast cancer.

Scattered Fibroglandular Density: this classification suggests a mix of fatty and fibroglandular tissue, leading to mammograms that exhibit both dense areas and darker regions. Women with this density have a slightly elevated risk of breast cancer compared to those with fatty breasts.

Heterogeneously Dense Breast Tissue: this indicates a higher proportion of fibroglandular rather than fatty tissue. The presence of heterogeneously dense breast tissue correlates with predisposing factors for breast cancer and complicates the detection of small tumors.

Extremely Dense Breast Tissue: in this classification, a significant majority of the breast tissue is fibroglandular, causing mammograms to appear nearly entirely white. This level of density exacerbates the risk of breast cancer and increases the chances of missed diagnoses during mammographic screenings [5].

Research has shown that higher breast density correlates with an increased risk of developing breast cancer. The fibroglandular tissue not only makes it more challenging for mammography to detect tumors but also is believed to have its own biological factors that could influence cancer development. Understanding these classifications is crucial for both clinicians and patients when assessing individual risk and determining the most appropriate screening strategies [6]. The biological relationship between breast density and cancer risk involves several factors, including hormonal influences, genetic predisposition, and the physical properties of breast tissue. Dense breast tissue is thought to be more responsive to hormonal changes, which can promote the growth of breast cancer cells. Additionally, certain genetic factors, such as mutations in BRCA1 and BRCA2 genes, are associated with both increased breast density and a higher risk of breast cancer [7, 8].

Recent studies have indicated that women with heterogeneously dense or extremely dense breasts not only have a higher risk of breast cancer but may also have different tumor characteristics, including more aggressive forms of the disease [9]. Understanding these biological underpinnings is essential for developing targeted screening protocols and interventions.

Breast cancer is a global health challenge, affecting millions of women each year. The World Health Organization (WHO) reports that breast cancer accounts for approximately 25% of all cancers diagnosed in women. The incidence of breast cancer varies significantly across regions due to differences in genetic, environmental, and lifestyle factors.

In high-income countries, the rates of breast cancer have increased over the past few decades, attributed in part to enhanced screening practices and better detection methods [10]. Conversely, in low- and middle-income countries, the rising incidence is concerning, often linked to a lack of access to screening and treatment options.

Numerous risk factors contribute to the development of breast cancer, including age, family history, genetic mutations, reproductive history, and lifestyle choices such as diet and physical activity [11]. Understanding these risk factors is essential for tailoring screening strategies to individual women based on their unique profiles.

Studies indicate that women with a family history of breast cancer have a significantly elevated risk. Additionally, certain ethnic groups, such as Ashkenazi Jews, have higher rates of BRCA mutations, further increasing their risk for breast cancer. Education about these risk factors is crucial for informed decision-making regarding screening.

Survival rates for breast cancer have improved over the years due to advances in early detection and treatment. The five-year survival rate for localized breast cancer is over 99%, highlighting the effectiveness of early diagnosis. However, disparities in survival rates persist,

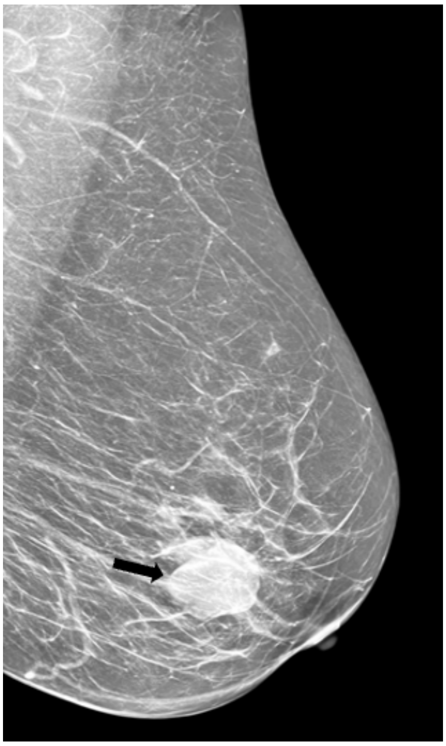

Fig. 2 (Рис. 2)

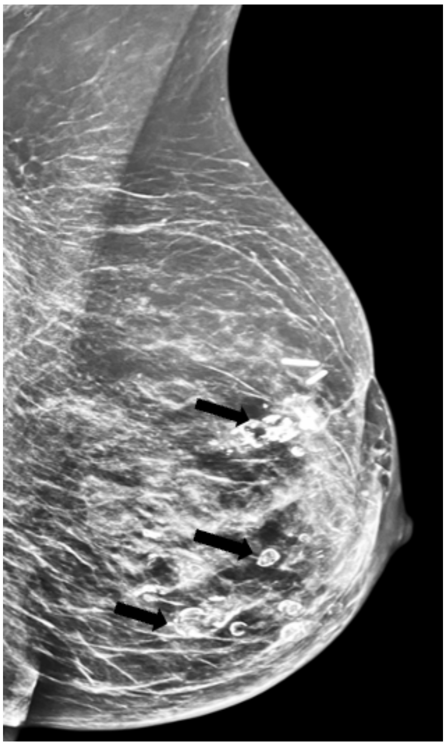

Fig. 3 (Рис. 3)

Fig. 2. Digital mammography with tomosynthesis.

Irregular hyperdense mass at the inner quadrants, measuring 3.6 x 3.0 cm (arrow), with indistinct margins. Scattered round calcifications are present. Due to a history of trauma, differentiation between malignancy and a post-traumatic hematoma is necessary. Illustration by the authors.

Рис. 2. Маммография с томосинтезом.

Гиперденсное образование неправильной формы в границе внутренних квадрантов, размером 3,6 x 3,0 см (стрелки) с неровными контурами. Также определяются единичные округлые кальцинаты. Необходимо дифференцировать между злокачественным новообразованием и посттравматической гематомой, учитывая анамнез травмы. Иллюстрация авторов.

Fig. 3. Digital mammography with tomosynthesis.

Area of altered architecture in the upper outer quadrant of the left breast, measuring up to 2.5 cm, with irregular shape and thickened contours. Multiple "clumped" calcifications and peripheral calcifications are noted (arrow), consistent with cysts/oleo granulomas. Illustration by the authors.

Рис. 3. Маммография с томосинтезом.

Участок измененной архитектоники в верхнем наружном квадранте, размером до 2,5 см, с тяжистыми контурами, втягивающий кожу. Определяются множественные «глыбчатые» кальцинаты и кальцинаты по типу пристеночных обызвествлений (стрелки) на фоне кист/олеогранулем. Иллюстрация авторов.

particularly among different socioeconomic groups and regions [12, 13].

Research indicates that access to timely diagnosis and effective treatment is paramount in improving outcomes. Efforts to enhance screening access, particularly for high-risk populations, are critical for reducing breast cancer mortality.

Limitations of Traditional Mammography.

Mammography is the most widely used screening tool for breast cancer, but it has notable limitations, especially for women with dense breast tissue. The primary challenge arises from the radiological characteristics of dense breasts: the high proportion of fibroglandular tissue can obscure tumors, making them difficult to detect. Studies show that mammography can miss up to 50% of cancers in women with heterogeneously dense or extremely dense breasts [14]. This limitation is concerning because it not only raises the risk of delayed diagnosis but also contributes to a higher incidence of interval cancers – tumors that become apparent between scheduled screenings. The emotional and psychological toll of such missed diagnoses is profound, as women may face advanced disease stages that could have been detected earlier with more sensitive imaging methods [15, 16].

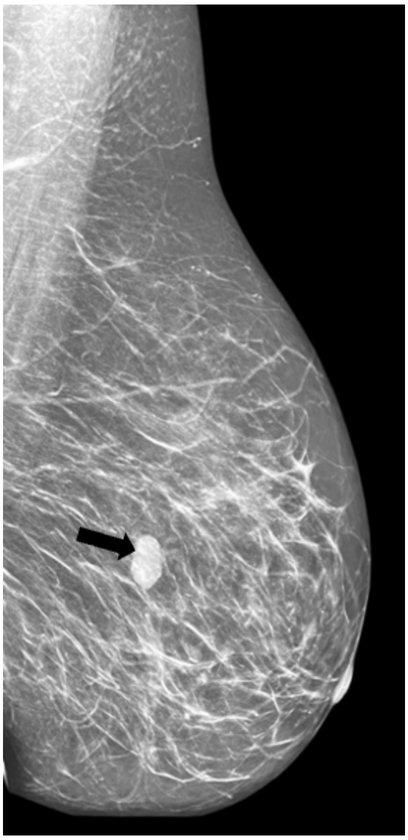

Fig. 4 (Рис. 4)

Fig. 5 (Рис. 5)

Fig. 4. Digital mammography with tomosynthesis.

Oval hyperdense mass at the border of the outer quadrants, measuring 1.8 x 1.3 cm (arrow), with well-defined lobulated contours (likely fibroadenoma). Single, round calcifications are noted. Illustration by the authors.

Рис. 4. Маммография с томосинтезом.

Гиперденсное образование овальной формы на границе наружных квадрантов, размером 1,8 х 1,3 см (стрелки) с четкими бугристыми контурами (вероятнее фиброаденома). Определяются единичные округлые кальцинаты. Иллюстрация авторов.

Fig. 5. Digital mammography with tomosynthesis.

Localized area of asymmetry in the upper quadrants, measuring up to 2.0 cm (стрелки), consistent with fibroglandular tissue. Single, round calcifications are noted bilaterally, along with oval and round shadows, measuring up to 0.5 cm, suggestive of cysts. Illustration by the authors.

Рис. 5. Маммография с томосинтезом.

Участок локальной асимметрии в верхних квадрантах, размером до 2,0 см (стрелки), соответствующий фиброзно-железистой ткани. Определяются единичные округлые кальцинаты с обеих сторон, а также овальные и круглые тени, размером до 0,5 см, предполагающие наличие кист. Иллюстрация авторов.

The diagnosis of non-palpable breast lesions, particularly in premenopausal women, presents unique challenges due to the high incidence of benign conditions and the limitations of traditional imaging modalities. It has been reported that 60-75% of non-palpable lesions are undetectable via ultrasound, complicating the diagnostic process and often leading to unnecessary biopsies. The study advocated for a comprehensive diagnostic strategy that includes advanced imaging techniques such as MRI and CT, which have demonstrated superior sensitivity and specificity in identifying malignant lesions [17]. Furthermore, the importance of implementing standardized screening protocols globally has been highlighted, emphasizing that early detection through advanced imaging can significantly improve patient outcomes [15]. By employing a multifaceted approach to diagnosis, healthcare providers can improve the accuracy of breast cancer detection, thereby enhancing patient management and treatment outcomes.

Interval cancers present a unique challenge. in breast cancer screening. These are

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cancers that are diagnosed after a negative mammogram but before the next scheduled screening. Research indicates that women with dense breast tissue are at a significantly higher risk for interval cancers, which are often more aggressive than those detected through regular screenings [18]. Understanding the nature of these cancers is essential. They tend to be larger and more advanced at the time of diagnosis, often leading to poorer outcomes. The emotional impact of receiving a cancer diagnosis shortly after being told there was "no sign of cancer" can be devastating, further complicating the overall healthcare experience for these patients.

Digital Breast Tomosynthesis (DBT).

Digital Breast Tomosynthesis (DBT), also known as 3D mammography, has emerged as a transformative technology in breast cancer screening, significantly improving the detection of malignant lesions compared to traditional two-dimensional (2D) mammography. By generating three-dimensional images of breast tissue, DBT allows radiologists to examine breast structures in layers, reducing the challenges posed by overlapping tissue that can obscure tumors. This advancement is particularly beneficial for women with dense breast tissue, a group at higher risk for breast cancer, where conventional mammography may be less effective. DBT utilizes a series of low-dose X-ray images taken from multiple angles to create a detailed 3D representation of the breast. The imaging protocol involves patient positioning similar to conventional mammography, where the breast is compressed between two plates. However, instead of capturing a single flat image, the X-ray tube moves in an arc over the breast, collecting multiple images that are reconstructed into a 3D model. This process enhances the visualization of breast structures, improving the ability to detect abnormalities more accurately.

One of the key advantages of DBT is its ability to improve cancer detection rates while reducing unnecessary recalls for additional imaging. When combined with conventional 2D mammography, DBT has been shown to enhance the identification of invasive cancers and improve the diagnostic accuracy for detecting microcalcification clusters, a common early sign of breast cancer. The increased clarity in imaging allows radiologists to better characterize lesions, including spiculated and distorted masses, leading to more precise diagnoses.

The ability of DBT to provide clearer images is particularly important for women with dense breast tissue, where traditional mammography may be limited. By improving lesion visibility and reducing the likelihood of obscured tumors, DBT enhances the overall effectiveness of breast cancer screening. Additionally, fewer recall appointments help alleviate patient anxiety and encourage continued participation in regular screenings.

his technology has proven especially beneficial for women with dense breast tissue, a demographic known for higher breast cancer risk and where conventional mammograms often yield less effective results. Studies have indicated that DBT can increase cancer detection rates by up to 41% and reduce false-positive recalls by about 15% when used as a primary screening tool [19].

Contrast-enhanced mammography.

Contrast-enhanced mammography integrates traditional mammography with the administration of an iodine-based contrast agent to enhance the visibility of breast lesions, particularly in patients with dense breast tissue. The process involves injecting a contrast agent into the bloodstream before capturing two sets of images – one without and one after the injection – allowing radiologists to better identify and characterize lesions by illustrating areas where the contrast has accumulated, indicating potential malignancies. CEM can improve diagnostic accuracy, especially for women with dense breasts where conventional mammography may be less effective, and it may also reduce false-positive rates compared to standard mammography, minimizing unnecessary follow-up procedures and patient anxiety. It has been found that CEM demonstrates higher sensitivity (88.9%) in detecting breast cancer in women with extremely dense breasts compared to low-energy (LE) imaging (27.8%), making it more effective in identifying cancers in this specific population. However, CEM does exhibit lower specificity (88.9%), which may lead to a higher rate of false positives compared to LE imaging (96.2%). Notably, the specificity of CEM improves at follow-up examinations, reaching 90.7%. In a study involving 1,299 screening CEM examinations, 16 screen-detected cancers and two interval cancers were identified, with five cancers depicted at LE imaging and an additional 11 detected through CEM. While the advantages of CEM are substantial, appropriate patient selection is crucial, as not all patients may require this imaging modality, and some may have contraindications for contrast use, such as allergies or renal impairment. Ongoing research is essential to establish standardized protocols and assess the long-term benefits of CEM across various populations, with potential integration of artificial intelligence and machine learning in interpreting CEM images to enhance clinical utility. Overall, CEM serves as a valuable tool in breast cancer detection and diagnosis, significantly impacting patient outcomes by effectively complementing other imaging modalities [20].

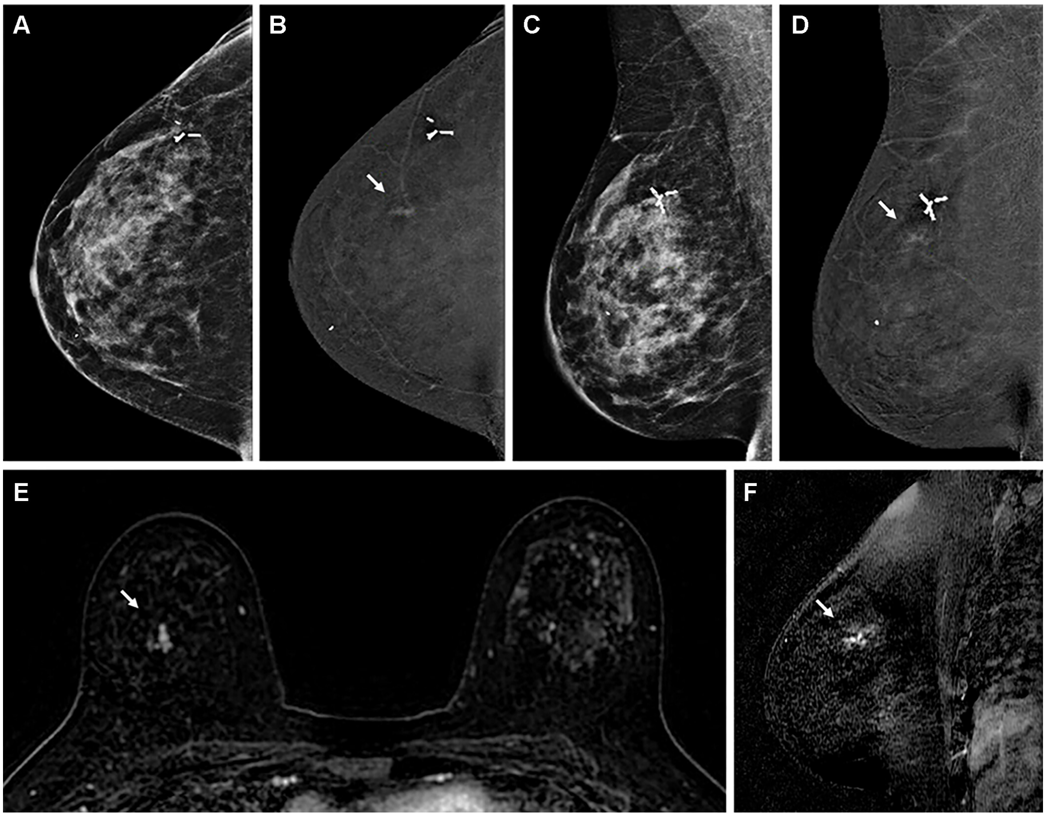

Fig. 6 (Рис. 6)

Fig. 6. A - D – Mammography with intravenous contrast. E, F – MRI.

A - D – 45-year-old female patient with a personal history of breast cancer. A, C – The screening images consist of low-energy (LE) craniocaudal and mediolateral oblique views; B, D – recombined craniocaudal and mediolateral oblique views. The cancer is visualized, confirmed by subsequent magnetic resonance imaging (E, F).
E – MRI, a diagnostic axial contrast-enhanced first subtraction image; F – a sagittal contrast-enhanced first subtraction image, which guided the MRI biopsy of the right breast. Pathologic examination following the MRI-guided biopsy revealed ductal carcinoma in situ with no nodal involvement [20].

Рис. 6. A - D – Маммография с внутривенным контрастированием. E, F – МРТ.

A - D – Пациентка, 45 лет, в анамнезе рак молочной железы. A, C – Скрининговые изображения, краниокаудальные и медиолатеральные косые проекции в режиме низкоэнергетических снимков; B, D – рекомбинированные изображения в тех же проекциях. Визуализируется опухоль, что подтверждается последующим магнитно-резонансным томографическим исследованием (E, F).

E – МРТ, диагностическое аксиальное контрастно-усиленное субтракционное изображение; F – МРТ, сагиттальное контрастно-усиленное субтракционное изображение; использовались для проведения биопсии под контролем МРТ в правой молочной железе. Гистологическое исследование после МРТ-биопсии выявило протоковый рак in situ без поражения лимфатических узлов [20].

Emergence of MRI as a screening tool.

Magnetic resonance imaging uses powerful magnets and radio waves to produce detailed images of the body's internal structures. Unlike mammography, MRI does not rely on ionizing radiation and is particularly adept at distinguishing between different types of tissues. In breast imaging, MRI is praised for its ability to provide high-resolution images that can reveal lesions obscured by dense breast tissue. Recent studies have shown that MRI significantly enhances cancer detection rates, particularly in women with dense breasts and negative mammograms. In fact, MRI demonstrated an incremental cancer detection rate (CDR) of 1.54 per 1,000 screenings, which is statistically superior to other supplemental modalities like handheld ultrasound (−0.35) and digital breast tomosynthesis (−0.14). These findings highlight MRI's crucial role as an adjunct screening tool, especially given its effectiveness in identifying small invasive cancers and ductal carcinoma in situ (DCIS), both of which

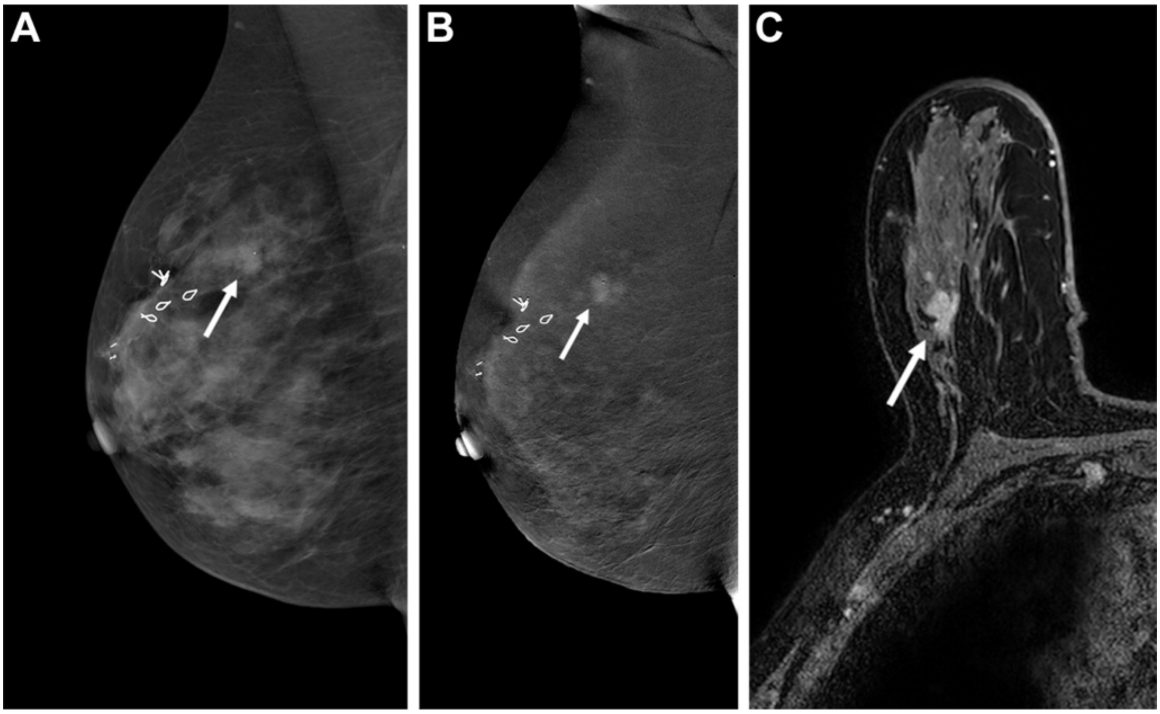

Fig. 7 (Рис. 7)

Fig. 7. A, B – Mammography with intravenous contrast. C – MRI.

A, B - Irregular mass in the upper outer quadrant of the right breast (Arrows) in a 73-year-old patient with a history of ductal carcinoma in situ.

C – MRI presents findings that confirm the suspicion, with pathology (arrow) identifying the lesion as recurrent invasive ductal carcinoma [22].

Рис. 7. А, В – Маммография с внутривенным контрастированием. С – МРТ.

А, В – Неправильной формы образование в верхне-наружном квадранте правой молочной железы (стрелки) у 73-летней пациентки с анамнезом протокового рака in situ.

С – МРТ, подтверждается наличие образования (стрелки), которое гистологически идентифицировано как рецидивирующий инвазивный протоковый рак [22].

are vital for improving long-term survival outcomes. As the need for effective screening increases, particularly among women with dense breast tissue, MRI's ability to detect previously hidden lesions underscores its potential as a leading option in breast cancer screening [21].

In assessing breast malignancies, imaging modalities like contrast-enhanced mammography (CEM) and MRI are essential. Figure 3 illustrates the findings for a 73-year-old woman with a history of ductal carcinoma in situ in the right breast and newly diagnosed invasive lobular carcinoma in the left breast.

The implementation of contrast agents, such as gadolinium, during MRI can further enhance visualization by highlighting areas of increased vascularity, which are often indicative of malignant growths. This makes MRI a powerful tool for early detection, especially in populations at high risk for breast cancer.

Comparative effectiveness of MRI vs. mammography.

Multiple studies have demonstrated the superior sensitivity of MRI compared to traditional mammography, particularly in women with dense breast tissue. Research shows that MRI can detect additional cancers that mammography may miss, with sensitivity rates reported as high as 93% for multicentric lesions and 88% for contralateral disease. This significant association between mammographic density and breast cancer risk emphasizes that women with dense breasts are more likely to benefit from MRI screenings due to the limitations of mammography in these populations. This underscores the importance of integrating MRI into screening protocols for women with dense breast tissue to enhance early detection and improve patient outcomes. The CONTRRAST trial aimed to evaluate the effectiveness of contrast-enhanced mammography (CEM) compared to magnetic resonance imaging in breast cancer detection, particularly

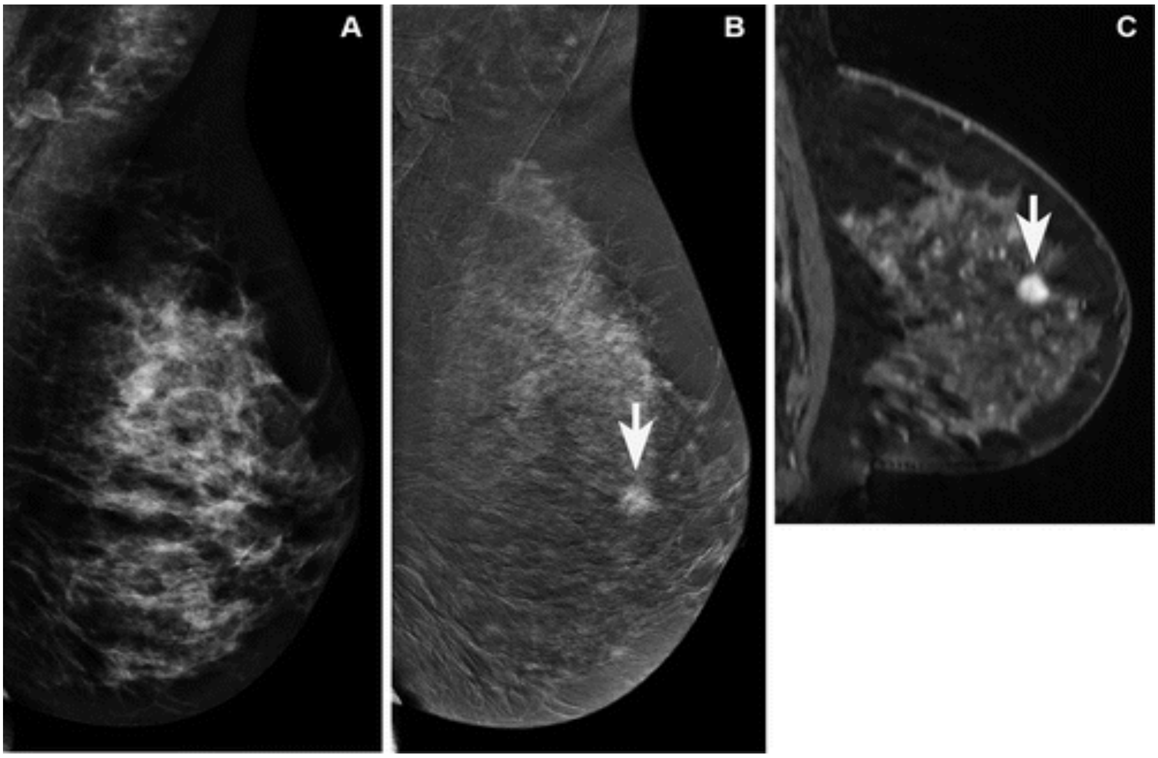

Fig. 8 (Рис. 8)

Fig. 8. A – standard two-dimensional mammogram, B – mammography with intravenous contrast, C – MRI, demonstrate a mass (white arrows), respectively.

Subsequent biopsy confirmed a 1.1 cm grade 2 invasive ductal carcinoma, positive for estrogen and progesterone receptors [23].

Рис. 8. А – стандартная двухмерная маммограмма, В – маммография с внутривенным контрастированием, С – МРТ. Образование (стрелки).

Биопсия подтвердила диагноз инвазивного протокового рака 2 степени дифференциации, размером 1,1 см, с положительными рецепторами эстрогена и прогестерона [23].

for women with dense breast tissue where traditional mammography may be less effective. Conducted as an enriched reader study, the trial involved multiple radiologists who reviewed images from both CEM and MRI to assess their diagnostic accuracy and detectability of breast lesions. The study included a diverse patient population at varying risk levels for breast cancer, providing a comprehensive evaluation of both imaging modalities. Key metrics analyzed included sensitivity, specificity, and cancer detection rates. The findings indicated that CEM offers comparable sensitivity to MRI while being more accessible and cost-effective. This is especially important given the limitations of MRI, which often include high costs and a scarcity of specialized equipment and trained personnel.

This figure illustrates the comparative results of CEM and MRI in detecting breast lesions, highlighting the advantages of CEM in visualizing abnormalities in dense breast tissue. The data suggest that CEM may identify additional cancers not detected by conventional mammography, reinforcing its potential as an effective adjunct screening tool. Ultimately, the CONTRAST trial contributes valuable insights to the ongoing discussion about optimal breast cancer screening strategies, suggesting that CEM can serve as a viable alternative, especially in settings where MRI is not readily available [24].

These findings underscore the potential of MRI not just as a supplemental tool but as a vital component of screening strategies for high-risk populations. Integrating MRI into routine screening protocols could lead to a significant reduction in the rates of missed diagnoses and interval cancers, ultimately improving survival rates.

Standard and abbreviated MRI protocols.

Standard MRI protocols for breast cancer screening typically involve several imaging sequences designed to capture comprehensive data about the breast tissue.

Key elements include:

1. Dynamic Contrast-Enhanced Imaging (DCE-MRI): this technique assesses tumor

vascularity by observing how lesions enhance over time with contrast agent administration. The enhancement patterns can help differentiate malignant from benign lesions.

2. Multiphase Imaging: this includes multiple imaging phases to ensure thorough examination of breast tissue and potential lesions. A multiphasic approach facilitates accurate lesion characterization and staging.

3. High Spatial Resolution: achieving high spatial resolution is critical for detecting small lesions. Techniques such as fat suppression are employed to enhance visibility in dense breast tissue.

4. Multiple Imaging Sequences: standard protocols often consist of T1-weighted, T2-weighted, and diffusion-weighted imaging, providing a robust dataset for comprehensive analysis.

The sensitivity and specificity of MRI in detecting breast cancer are significant factors influencing its integration into screening protocols. Studies suggest that MRI can achieve sensitivity rates comparable to those of standard protocols, effectively identifying malignancies that may remain undetected through conventional mammography [25]. However, the challenge remains in balancing the high sensitivity of MRI with its potential for false positives. While false positives can lead to unnecessary biopsies and increased anxiety, the benefits of earlier and more accurate detection of cancer often outweigh these concerns, particularly in women with dense breast tissue.

Multiparametric MRI.

Multiparametric MRI (mpMRI) is an advanced imaging technique that combines multiple MRI sequences to provide a comprehensive evaluation of tissue characteristics. By integrating functional and anatomical imaging, mpMRI enhances the detection, characterisation, and staging of various pathologies, including cancer. MpMRI has emerged as a pivotal tool, particularly for patients with dense breast tissue. Conventional imaging techniques, such as mammography and ultrasound, may be limited in sensitivity for detecting malignancies in dense breast tissue. mpMRI, however, offers superior soft tissue contrast and functional assessment, improving diagnostic accuracy.

The complexity of interpreting mpMRI images necessitates a structured approach to reduce false-positive findings. One such structured approach is the Kaiser score – a clinical decision rule that integrates multiple Breast Imaging Reporting and Data System (BI-RADS) criteria. The Kaiser score provides radiologists with a systematic method for assessing malignancy probabilities, thereby enhancing diagnostic precision and reducing inter-observer variability [26]. This is particularly beneficial for radiologists with varying levels of experience, ensuring a more consistent and reliable assessment of breast lesions. The ability of mpMRI to assess multiple tissue parameters – such as diffusion, perfusion, and metabolic activity – makes it a versatile and invaluable tool in modern radiology.

The evolving discourse on breast cancer screening reveals significant advancements in methodologies that emphasize personalized approaches and equity in healthcare. A critical examination of current paradigms shows the need to balance efficacy, personalization, and access within screening programs. Traditional screening strategies often rely on a one-size-fits-all model, which can overlook the diverse needs and risk profiles of various populations. Emphasizing personalized screening methodologies suggests that factors such as genetic predisposition, personal medical history, and breast density should play crucial roles in determining screening protocols. This personalized approach is especially vital for addressing health disparities, given that not all demographic groups have equal access to screening technologies or the same levels of participation, resulting in delayed diagnoses and poorer outcomes for specific factions of the population. Emerging technologies in breast cancer detection further support the argument for evolving guidelines that integrate advanced methods, thus enhancing the efficacy of screening programs [27].

In conjunction with this perspective, recent findings on the effectiveness of supplemental MRI screening for women with dense breasts who have previously received negative mammography results provide compelling evidence for the necessity of tailored screening approaches. The preliminary results reveal that MRI significantly improves detection rates in this high-risk group, where traditional mammography may fall short due to reduced sensitivity [27, 28].

Microstructural diffusion MRI in breast cancer diagnosis.

Microstructural diffusion MRI is a promising non-invasive imaging technique that provides valuable insights into the cellular structure and organization of breast tissue, especially in the context of breast cancer diagnosis. The technique measures the diffusion of water molecules within the tissue, a process significantly influenced by the presence of cancer cells and their surrounding microenvironment. By analyzing changes in water diffusion patterns, microstructural diffusion MRI can help detect and characterize tumors, offering critical information about cellular characteristics such as cell density and membrane integrity. This capability is essential for distinguishing between benign and malignant lesions and assessing tumor aggressiveness,

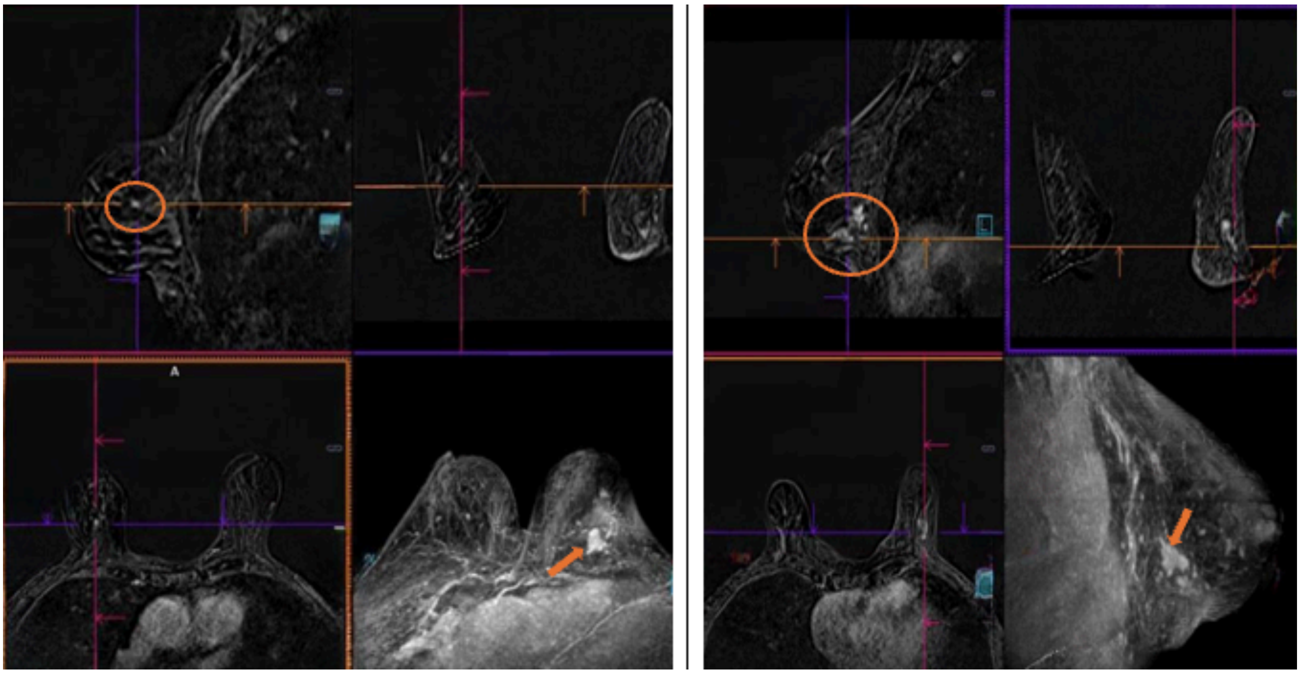

Fig. 9 (Рис. 9)

Fig. 9. **Breast MRI.**

Standardized program for obtaining diffusion-weighted images, T2-weighted images without suppressing the signal from adipose tissue, T1-weighted images with suppressing the signal from adipose tissue, dynamic post-contrast images and images in the subtraction mode.

In the right breast, two small oval-shaped lesions with smooth, well-defined contours and persistent contrast enhancement were identified in the upper outer quadrant, likely benign fibroadenomas (BI-RADS 3).

In the left breast, an irregularly shaped lesion (Arrow) near the pectoral muscle (2.0×1.6×1.3 cm) displayed 100% enhancement at 120 seconds, with additional non-mass enhancement areas, one measuring 1.5×0.8 cm with less than 50% enhancement in the first phase and another subcutaneous region (1.3×0.6 cm) with grouped foci of contrast uptake, both raising suspicion for malignancy (BI-RADS 5). Additional findings included moderate adenosis bilaterally, a few small cysts in the left breast, and no abnormalities in axillary lymph nodes. Mammography with tomosynthesis confirmed the presence of dense, heterogeneous fibroglandular breast tissue (type C). Illustrations by the authors.

Рис. 9. **МРТ молочных желез.**

Стандартизованная программа с получением диффузионно-взвешенных изображений, Т2-взвешенных изображений без подавления сигнала от жировой ткани, Т1-взвешенных изображений с подавлением сигнала от жировой ткани, динамических постконтрастных изображений и изображений в режиме субтракции.

В правой молочной железе в верхнем наружном квадранте обнаружено два небольших очага овальной формы с ровными, четко очерченными контурами и стойким контрастным усилением, вероятно, доброкачественные фиброаденомы (BI-RADS 3).

В левой молочной железе образование неправильной формы (стрелки) около грудной мышцы (2,0×1,6×1,3 см) увеличивалось на 100% за 120 секунд, с дополнительными участками увеличения, не имеющими массы, один из которых был размером 1,5×0,8 см с увеличением менее чем на 50% на первом этапе, и другой областью подкожно (1,3×0,6 см) со сгруппированными очагами поглощения контраста, оба из которых вызывают подозрение на злокачественность (BI-RADS 5). Дополнительные данные включали умеренный двусторонний аденоз, несколько небольших кист в левой молочной железе и отсутствие патологии в подмышечных лимфатических узлах. Маммография с использованием томосинтеза подтвердила наличие плотной, гетерогенной фиброгландулярной ткани молочной железы (тип С). Иллюстрации авторов.

ultimately contributing to more accurate diagnoses and informed treatment planning. In microstructural diffusion MRI, cells are characterized based on alterations in water diffusion behavior. In healthy breast tissue, water diffusion is relatively unrestricted due to larger extracellular spaces, allowing for greater movement [28]. Conversely, in cancerous tissues, the increased cell density and disrupted membranes create barriers that hinder water diffusion, resulting in distinct patterns that can be analyzed to differentiate between healthy and cancerous tissues.

While this innovative technique presents significant advantages over traditional imaging methods, such as reduced reliance on invasive biopsies and improved monitoring of treatment responses, it is still an evolving field. Ongoing research is essential to refine analysis techniques and fully establish the clinical utility of microstructural diffusion MRI. The findings so far suggest its potential to enhance early detection and diagnosis of breast cancer, promoting timely interventions and improving patient outcomes [29]. As the technique continues to develop, further validation through comparative studies with traditional MRI methods will be crucial for enhancing the diagnostic landscape for breast cancer

Role of artificial intelligence and machine learning.

Recent advancements in artificial intelligence (AI) and machine learning are transforming the landscape of breast imaging. These technologies have the potential to enhance diagnostic accuracy by analyzing imaging data more efficiently than traditional methods. AI algorithms can assist radiologists in identifying subtle lesions that may be missed by the human eye, thereby improving sensitivity and specificity. Furthermore, machine learning models can help predict a woman's risk of developing breast cancer based on a multitude of factors, allowing for more personalized screening approaches.

AI algorithms can be trained to analyze mammograms with remarkable precision, effectively identifying lesions hidden within dense breast tissue. AI systems can process vast amounts of imaging data rapidly, learning to distinguish between benign and malignant features. This capability not only increases the likelihood of early detection but also improves overall diagnostic confidence among radiologists [30].

In addition, the implementation of AI in mammography has been shown to reduce false-positive rates, thus minimizing unnecessary biopsies and patient anxiety. AI-enhanced detection methods demonstrate significant potential in improving specificity, allowing for a more accurate assessment of breast tissue without the drawbacks often associated with traditional screening techniques. The synergistic application of AI with other imaging modalities further enriches the diagnostic process for women with dense breasts. By combining mammography with supplemental imaging techniques, such as ultrasound and MRI, AI can provide comprehensive analyses that enhance the detection of multicentric and contralateral disease [31].

Despite the promising advancements, several challenges remain in the widespread adoption of AI in breast cancer diagnosis. The need for standardized protocols for AI training and validation is critical. Ensuring that AI systems are developed using diverse and representative datasets will be vital for their effectiveness in clinical settings. Moreover, the healthcare community must navigate the integration of AI into existing workflows. Radiologists will require appropriate training to interpret AI-generated insights effectively, balancing technological assistance with their clinical expertise [31].

The literature highlights a critical need for further research to establish standardized protocols for MRI screening, taking into consideration timing and frequency based on breast density and individual risk factors. As the definitions of breast density evolve, a well-defined strategy to incorporate MRI alongside traditional screening methods becomes essential. Effective communication surrounding the merits of supplemental MRI screening is fundamental for both healthcare providers and patients, with education playing a vital role in bridging existing knowledge gaps and improving screening compliance.

Ongoing trials, such as the DENSE trial, provide invaluable insights critical for refining MRI's role in evolving screening guidelines. Innovation in breast cancer imaging continues to be fueled by advancements in AI and machine learning. Emerging studies indicate these technologies may enhance the role of MRI in screening by improving diagnostic accuracy and facilitating the identification of subtle lesions more effectively.

A comparative study encompassing mammography enhanced by AI, alongside mammography and supplemental ultrasound (US), reveals important findings. The study indicates that mammography with AI exhibits higher specificity (95.3%) and lower false-positive rates (5.0%) than standard mammography. Conversely, the combination of mammography plus US demonstrates a higher cancer detection rate (5.6 per 1000 examinations) and sensitivity (97.0%), despite lower specificity and higher false-positive rates. These results illuminate the importance of complementary screening methods in women with dense breasts, enhancing the balance between specificity, sensitivity, and early detection [31, 32].

Conclusion.

In conclusion, multiparametric MRI offers significant advantages for diagnosing breast cancer in patients with dense breast tissue, where conventional methods may fail. By integrating MRI with standard mammography, a more effective approach to early detection and treatment planning is facilitated. Future research should focus on refining these techniques and enhancing their application in clinical settings to improve patient outcomes.

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