INTERNATIONAL MULTIDISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
SJIF 2019: 5.222 2020: 5.552 2021: 5.637 2022:5.479 2023:6.563 2024: 7,805
eISSN :2394-6334 https://www.ijmrd.in/index.php/imjrd Volume 12, issue 05 (2025)

THE ROLE OF SCREENING IN THE EARLY DETECTION OF BREAST CANCER: A CONTEMPORARY PERSPECTIVE

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Abstract: Malignant neoplasms of the breast remain one of the leading causes of death rate among women. Screening programs aim to detect the disease before the onset of clinical symptoms, significantly improving therapeutic intervention outcomes. This article reviews modern approaches to breast cancer preventive diagnostics, including X-ray breast imaging, sonographic examination diagnostics, magnetic resonance imaging, and tomosynthesis. It also discusses the prospects of implementing individualized preventive diagnostics strategies and artificial intelligence technologies in imaging diagnostics.
Keywords: breast cancer, prevention, X-ray breast imaging, imaging, sonographic examination, magnetic resonance imaging, tomosynthesis.

1. Introduction

Mammary carcinoma is the most commonly diagnosed malignancy among women and a leading cause of cancer-related deaths worldwide. According to the World Health Organization, more than 2.3 million women were diagnosed with breast cancer in 2020, and approximately 685,000 died from the disease globally. The burden of breast cancer is growing, particularly in low- and middle-income countries where early identification and access to effective therapeutic intervention are often limited.

The importance of early identification has been well-documented. Screening allows for the identification of cancer at an earlier, more treatable stage before the appearance of clinical symptoms. Numerous studies have shown that regular preventive diagnostics significantly reduces breast cancer death rate, especially in women aged 50 to 69 years.

Historically, X-ray breast imaging has been the cornerstone of breast cancer preventive diagnostics programs due to its proven efficacy in detecting early-stage tumors. However, technological advancements have led to the development of additional imaging modalities, such as sonographic examination, magnetic resonance imaging (MRI), and digital breast tomosynthesis (DBT). Each modality has its advantages and limitations, and the choice of preventive diagnostics strategy increasingly depends on patient-specific factors, including age, breast density, and genetic likelihood.

Moreover, emerging technologies such as artificial intelligence (artificial intelligence systems) in medical imaging and molecular diagnostics are transforming the landscape of breast cancer preventive diagnostics. These innovations offer the potential to enhance diagnostic diagnostic precision, reduce interpretive errors, and tailor preventive diagnostics approaches to individual likelihood profiles.

This paper provides a contemporary perspective on breast cancer preventive diagnostics, examining traditional and emerging modalities, their effectiveness, and future directions in personalized preventive diagnostics strategies.

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2. Methods

This article employs a narrative review methodology, synthesizing current literature related to breast cancer preventive diagnostics techniques, program implementation, and emerging technologies. The primary objective was to evaluate the efficacy, advantages, and limitations of various preventive diagnostics modalities in order to assess their roles in early identification of breast cancer.

Sources for this review were collected from peer-reviewed journals, reports by international health organizations (such as the World Health Organization, the U.S. Preventive Services Task Force, and the European Society of Breast Imaging), and clinical guidelines. Search engines including PubMed, Scopus, and Google Scholar were used to identify relevant literature. Search terms included 'breast cancer preventive diagnostics', 'X-ray breast imaging', 'sonographic examination in breast cancer', 'magnetic resonance imaging breast cancer', 'tomosynthesis', 'artificial intelligence in radiology', and 'early identification'.

Inclusion criteria were as follows:
- Articles published between 2000 and 2024
- Studies discussing the preventive diagnostics of asymptomatic women
- Studies evaluating diagnostic diagnostic precision, sensitivity, and specificity
- Research involving human subjects and relevant guidelines

Excluded were studies not focused on early identification or lacking clinical relevance. Emphasis was placed on systematic reviews, randomized controlled trials, and large cohort studies to ensure data quality and reliability.

The analysis also included statistical modeling and outcome comparisons of population-based preventive diagnostics programs across various countries. Studies in English and Russian were considered to expand the review scope.

3. Results

3.1 Mammography

Mammography remains the primary and most widely used method of breast cancer preventive diagnostics globally. It involves the use of low-dose X-rays to detect abnormalities in breast tissue, particularly microcalcifications and masses. Mammography has demonstrated high sensitivity and specificity in detecting early-stage cancers, particularly in postmenopausal women.

Numerous large-scale studies, including the Swedish Two-County Trial and the UK Age Trial, have confirmed that X-ray breast imaging preventive diagnostics significantly reduces death rate by enabling earlier diagnosis. It is recommended by most health organizations for women aged 50 to 69 years, with preventive diagnostics intervals of one to two years. Digital X-ray breast imaging has largely replaced film-based approaches due to improved image quality and easier data storage.

However, X-ray breast imaging’s sensitivity decreases in women with dense breast tissue, which is more prevalent in younger women. In such cases, lesions may be obscured by overlapping glandular tissue, leading to false-negative results.

3.2 Ultrasound

Ultrasound imaging is commonly used as a supplemental preventive diagnostics tool, particularly for women with dense breasts. It uses high-frequency sound waves to generate images and is non-invasive, widely accessible, and relatively low-cost.

Breast sonographic examination is effective in differentiating cystic from solid lesions and detecting abnormalities that may be missed by X-ray breast imaging. It is particularly useful in younger populations and in areas with limited access to X-ray breast imaging. Automated breast sonographic examination systems (ABUS) have been developed to improve reproducibility and reduce operator dependency.

Nonetheless, sonographic examination is more prone to false positives and typically has lower specificity than X-ray breast imaging, which may result in unnecessary biopsies and anxiety. It is not recommended as a standalone preventive diagnostics method but adds value when used in conjunction with X-ray breast imaging.

3.3 Magnetic Resonance Imaging (MRI)

magnetic resonance imaging offers superior soft tissue contrast and is highly sensitive in detecting invasive cancers, especially in high-likelihood women, such as BRCA1/2 mutation carriers. It does not use ionizing radiation and provides detailed anatomical and functional information.

Contrast-enhanced magnetic resonance imaging can detect tumors not visible on X-ray breast imaging or sonographic examination, making it ideal for women with dense breasts or prior inconclusive imaging results. According to the American Cancer Society, annual magnetic resonance imaging preventive diagnosticss are recommended for women with a lifetime breast cancer likelihood of 20% or greater.

Despite its advantages, magnetic resonance imaging is expensive, less accessible, and may yield false positives. It also requires intravenous contrast, which may pose likelihoods for some individuals.

3.4 Digital Breast Tomosynthesis (DBT)

DBT, or 3D X-ray breast imaging, is a recent advancement that captures multiple images of the breast from different angles, creating a three-dimensional reconstruction. It enhances cancer identification rates, particularly in women with dense breast tissue.

Studies have shown that DBT improves lesion visualization, reduces recall rates, and increases diagnostic diagnostic precision compared to conventional X-ray breast imaging. However, it is not yet universally available and may involve slightly higher radiation doses.

DBT is increasingly being integrated into population-based preventive diagnostics programs, especially in the United States and parts of Europe.

3.5 Emerging Technologies and Innovations

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Artificial intelligence (artificial intelligence systems) is revolutionizing breast cancer preventive diagnostics by enhancing image interpretation, reducing radiologist workload, and improving identification rates. artificial intelligence systems algorithms can assist in identifying subtle abnormalities and standardizing image assessment.

Liquid biopsy is another emerging tool, analyzing circulating tumor DNA or other biomarkers from a blood sample. Though still under investigation, it holds potential for non-invasive early cancer identification.

Molecular breast imaging (MBI) and positron emission X-ray breast imaging (PEM) are also under exploration as adjunct preventive diagnostics tools, particularly in high-likelihood populations. These techniques aim to identify functional changes at the cellular level before anatomical alterations occur.

4. Discussion

The findings from this review underscore the critical role of preventive diagnostics in the early identification of breast cancer. While traditional approaches like X-ray breast imaging continue to form the cornerstone of preventive diagnostics programs, the integration of advanced imaging technologies and personalized strategies is transforming clinical practice.

Mammography remains the most cost-effective and widely available preventive diagnostics method, particularly effective for women aged 50–69. However, its reduced sensitivity in dense breast tissue necessitates supplemental modalities. Ultrasound, when used adjunctively, improves cancer identification rates in women with dense breasts and in younger populations. magnetic resonance imaging, although costly, provides unmatched sensitivity for high-likelihood individuals and is recommended in specific clinical guidelines for individuals with known genetic mutations or significant family histories.

The addition of digital breast tomosynthesis (DBT) has improved lesion identification and decreased recall rates, particularly in heterogeneous breast density. Nonetheless, accessibility and cost remain limiting factors in its widespread adoption.

Emerging technologies like artificial intelligence (artificial intelligence systems) are promising in addressing the limitations of human interpretation. artificial intelligence systems-assisted reading can increase diagnostic diagnostic precision, reduce false-positive rates, and standardize assessment. Studies suggest that artificial intelligence systems can perform comparably to experienced radiologists, especially when combined with conventional techniques.

Liquid biopsy and molecular imaging modalities are still under development but represent the future of highly sensitive, non-invasive preventive diagnostics options. These technologies offer the potential to detect malignancy at the molecular level before anatomical changes are evident.

However, despite the technological progress, several challenges persist:
- **Overdiagnosis and overtherapeutic intervention**: Screening can detect slow-growing or indolent tumors that may never become clinically significant.
- **Access and equity**: In low-resource settings, access to preventive diagnostics is limited by infrastructural, economic, and educational barriers.
- **Psychosocial implications**: False positives and unnecessary interventions can cause

emotional distress and economic burden.

International preventive diagnostics strategies vary significantly. In Europe, population-based preventive diagnostics with centralized follow-up is common. The U.S. employs a more opportunistic model, often influenced by insurance coverage. Both models have strengths and limitations, highlighting the need for tailored approaches based on regional healthcare infrastructure and population characteristics.

Personalized preventive diagnostics—based on individual likelihood profiles, including age, breast density, hormonal status, and genetic predisposition—is becoming the new paradigm. Risk prediction models such as the Gail Model and Tyrer-Cuzick model are already guiding clinical decisions.

Ultimately, optimizing breast cancer preventive diagnostics requires a multi-faceted approach: integrating emerging technologies, enhancing access, improving public education, and developing policies that balance benefits with potential harms.

5. Conclusion

Mammary carcinoma preventive diagnostics has undergone substantial transformation over recent decades, evolving from conventional X-ray breast imaging to a more diversified, technological solutions-driven, and individualized approach. The incorporation of supplemental imaging techniques such as sonographic examination, magnetic resonance imaging, and tomosynthesis has improved diagnostic diagnostic precision, particularly among high-likelihood and younger populations.

The growing application of artificial intelligence and molecular diagnostics is poised to revolutionize early identification, enhancing precision and reducing variability in interpretation. Furthermore, the trend toward likelihood-stratified preventive diagnostics promises to optimize resource allocation and patient outcomes by tailoring preventive diagnostics strategies to individual needs.

Nonetheless, challenges such as overdiagnosis, limited access in underserved regions, and infrastructure deficits remain barriers to the universal effectiveness of preventive diagnostics programs. Addressing these requires international collaboration, public education, investment in healthcare infrastructure, and ongoing research into innovative technologies.

In conclusion, while significant progress has been made, the continued refinement of breast cancer preventive diagnostics strategies is essential to further reduce death rate and improve quality of life for women worldwide.

6. Comparative Characteristics of Breast Cancer Screening Methods

Method	Advantages	Limitations	Recommended Group
Mammography	Good sensitivity, widely available	Reduced accuracy with dense tissue	Women aged 50–69
Ultrasound	Non-invasive, helpful with dense tissue	Lower specificity, operator-dependent	Women under 40 or with dense breasts
MRI	High sensitivity, ideal for high-risk groups	Expensive, requires contrast	BRCA mutation carriers, lifetime risk

			≥20%
Tomosynthesis	3D imaging, reduces recall rates	Limited availability, slightly higher radiation	Women with dense breasts
AI/Deep Learning	Improves accuracy, reduces human error	Requires validation and regulation	In development and pilot use

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