

## BREAST CANCER DIAGNOSIS: MODERN METHODS, CLINICAL APPROACHES AND EARLY DETECTION STRATEGIES

**Zaripboyeva Sevinch Gofur kizi**

*First-Year Student of Navoi State University, Faculty of Medicine*

**Sayfullaev Akmal Karimovich**

*Teacher of General Medical Sciences, Navoi State University*

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*Breast cancer remains one of the most common malignancies affecting women globally, with early identification playing a critical role in improving survival rates and reducing the need for extensive treatments. This article examines contemporary diagnostic techniques, clinical evaluation methods, and strategies for prompt identification of the disease. Conventional imaging approaches such as mammography continue to serve as foundational tools, yet advancements including digital breast tomosynthesis, magnetic resonance imaging, and ultrasound have enhanced accuracy, particularly in women with dense breast tissue. Emerging technologies, including artificial intelligence applications in image analysis, biosensor platforms targeting specific biomarkers in blood, saliva, urine, sweat, and breath, as well as wearable devices like smart bras equipped with thermosensors and microwave imaging components, offer non-invasive, patient-friendly alternatives that support continuous monitoring and personalized risk assessment. Clinical approaches integrate physical examination, patient history review, and risk stratification based*

*on genetic factors and family background to guide diagnostic pathways. Early detection programs emphasize population-based screening tailored to age groups and individual risk levels, incorporating multimodal strategies that combine traditional and innovative methods to minimize false positives and negatives while maximizing accessibility in diverse healthcare settings. Literature synthesis reveals that these integrated approaches can achieve detection sensitivities exceeding ninety percent in early stages, leading to survival rates approaching ninety percent for localized disease. Challenges persist in cost-effectiveness, standardization, and equitable access, especially in resource-limited regions. Future directions point toward hybrid systems that fuse artificial intelligence with biosensors and wearable technologies for real-time, precise diagnostics. This comprehensive review underscores the transformative potential of modern methods in shifting breast cancer management from reactive treatment to proactive, preventive care, ultimately contributing to reduced mortality and improved quality of life for affected individuals. The discussion highlights evidence from recent studies demonstrating superior performance of combined modalities over single techniques alone, with emphasis on clinical implementation and strategic frameworks for widespread adoption. Overall, the integration of these elements promises a paradigm shift in breast cancer care by the year two thousand thirty.*

**Introduction**

Breast cancer continues to represent a significant public health challenge worldwide, accounting for a substantial proportion of cancer-related deaths among women. The disease arises from uncontrolled proliferation of cells in breast tissue, often influenced by genetic predispositions, hormonal factors, lifestyle elements, and environmental exposures. Timely recognition of the condition is essential because localized tumors respond far more favorably to therapeutic interventions than those that have spread to lymph nodes or distant organs. Modern diagnostic frameworks have evolved beyond traditional reliance on symptom reporting and basic physical assessments to encompass sophisticated imaging, molecular analysis, and technology-assisted tools that facilitate identification before clinical manifestations become apparent.

Clinical approaches begin with thorough patient history collection, including inquiries about family occurrences of the malignancy, reproductive history, hormone replacement therapy use, and personal risk factors such as increased body mass index or alcohol consumption. Physical examination of the breasts and axillary regions provides initial clues, yet it lacks the sensitivity required for reliable early-stage detection on its own. Therefore, integration with advanced methods forms the cornerstone of contemporary practice. Early detection strategies focus on systematic screening initiatives designed for asymptomatic populations, customized according to age, genetic profile, and overall health status. These programs aim not only to identify abnormalities at the smallest detectable sizes but also to stratify individuals into risk categories that dictate the intensity and frequency of monitoring.

Recent innovations have introduced non-invasive options that address limitations of older techniques, such as exposure to ionizing radiation or discomfort associated with compression during imaging procedures. For instance, wearable technologies enable ongoing surveillance in everyday environments, while biosensor platforms analyze bodily fluids for molecular signatures indicative of malignant transformation. Artificial intelligence algorithms further refine interpretations of complex datasets, reducing human error and accelerating decision-making processes. This article explores these elements in depth, drawing upon current evidence to illustrate how combined methodologies enhance diagnostic precision, clinical decision-making, and population-level outcomes. By synthesizing available knowledge, the review seeks to inform healthcare providers, policymakers, and researchers about optimal pathways for implementing these advancements in routine care settings. The emphasis remains on practical applicability, cost

considerations, and the potential to extend benefits to underserved communities where access to specialized equipment may be constrained. Through this lens, breast cancer diagnosis emerges as a dynamic field poised for continued progress that prioritizes prevention, accuracy, and patient-centered design.

**Literature review**

Extensive research has documented the evolution of breast cancer diagnostic tools, highlighting both established practices and cutting-edge developments. Conventional imaging remains central, with mammography serving as the primary screening modality due to its ability to visualize structural changes such as masses or microcalcifications. Digital breast tomosynthesis improves upon standard two-dimensional mammography by generating three-dimensional reconstructions that reduce tissue overlap and enhance detection rates, particularly in dense breast parenchyma where conventional methods often underperform. Studies indicate that digital breast tomosynthesis identifies fifteen to thirty percent more cancers while decreasing recall rates by fifteen to twenty percent compared with traditional approaches.

Magnetic resonance imaging offers superior sensitivity, ranging from seventy-five to one hundred percent, making it valuable for supplemental screening in high-risk individuals. This technique excels at delineating soft-tissue contrast without ionizing radiation, though its specificity can vary and often necessitates additional confirmatory procedures to distinguish benign from malignant lesions. Ultrasound complements these methods by providing real-time evaluation, especially for palpable abnormalities or in younger patients with denser tissue, achieving sensitivity levels of eighty to eighty-nine percent. Automated variants further standardize the process and improve consistency across operators. Positron emission tomography combined with computed tomography delivers metabolic information useful for staging and treatment monitoring, with high sensitivity for lesions larger than eight millimeters, yet its routine application in early detection remains limited by cost and availability.

Emerging biosensor technologies have expanded diagnostic capabilities by targeting circulating biomarkers such as carbohydrate antigen fifteen-three, human epidermal growth factor receptor two, and various micro ribonucleic acids. Electrochemical and optical biosensor platforms demonstrate exceptional limits of detection, sometimes reaching femtomolar or picomolar concentrations in blood, saliva, urine, or sweat samples. For example, field-effect transistor-based sensors in saliva achieve detection thresholds as low as one femtogram per milliliter for key markers, enabling rapid, minimally invasive

assessment suitable for point-of-care use. Breath analysis employing electronic nose systems, enhanced by machine learning classification, reports accuracies exceeding ninety percent in distinguishing malignant from non-malignant profiles through volatile organic compound patterns. Sweat and urine samples similarly yield promising results when analyzed via gas chromatography-mass spectrometry coupled with artificial intelligence, offering entirely non-invasive collection methods that support frequent self-monitoring.

Wearable devices represent another frontier, integrating thermosensors, piezoresistive elements, and microwave antennas into garments such as specialized bras. These systems detect subtle temperature variations or tissue elasticity changes associated with early tumor formation, providing continuous data streams transmitted wirelessly for remote analysis. Pilot evaluations show detection of small cysts around three millimeters with promising accuracy, and integration with artificial intelligence algorithms further refines signal interpretation to minimize false alarms. Microwave imaging within these platforms leverages dielectric property differences between healthy and malignant tissue, proving particularly effective in dense breasts where other modalities struggle.

Artificial intelligence applications have revolutionized image interpretation across all modalities. Deep learning models, including convolutional neural networks and vision transformers, achieve area under the curve values above zero point nine for lesion detection and classification in mammography and digital breast tomosynthesis datasets. In magnetic resonance imaging, these algorithms facilitate automated segmentation of tumor volumes and fibroglandular tissue with dice similarity coefficients exceeding zero point eight, while multimodal fusion improves molecular subtyping predictions. Ultrasound analysis benefits from attention mechanisms that address operator variability, and even positron emission tomography data gains from radiomics features that enhance prognostic accuracy. Large foundation models show potential for generating structured reports and supporting risk stratification by incorporating imaging, genomic, and clinical variables. Federated learning approaches address data privacy concerns by enabling collaborative training across institutions without centralizing sensitive information.

Screening guidelines from major organizations provide structured frameworks for implementation. Recommendations advocate annual mammography for women aged forty-five to fifty-four at average risk, with options to begin earlier between forty and forty-four and to transition to biennial intervals after age fifty-five for those in good health. High-risk categories, defined by lifetime probability exceeding twenty percent or specific genetic mutations, warrant combined mammography and magnetic resonance imaging starting at

age thirty. These protocols emphasize shared decision-making that weighs benefits against potential harms such as overdiagnosis or unnecessary biopsies. Global initiatives stress health promotion, timely diagnosis, and comprehensive management to reduce disparities in outcomes across regions.

Collectively, the literature demonstrates a clear progression toward multimodal, technology-enhanced strategies that address the shortcomings of isolated techniques. Biosensors and wearables extend reach beyond clinical facilities, while artificial intelligence augments human expertise to achieve comparable or superior performance metrics. Challenges include the need for larger validation cohorts, standardization of protocols, and equitable distribution of resources to ensure these innovations benefit all populations. Nonetheless, the reviewed evidence supports the feasibility of shifting toward precision-oriented diagnostics that prioritize early intervention and individualized care pathways.

### Discussion

Integration of modern methods with clinical approaches yields substantial advantages in breast cancer diagnosis, yet requires careful consideration of practical implementation factors. Clinical evaluation forms the initial gateway, where detailed history and physical assessment identify candidates for immediate imaging or biomarker testing. Risk stratification tools incorporating genetic profiling and lifestyle data guide the selection of supplemental modalities, ensuring that high-risk individuals receive magnetic resonance imaging alongside standard mammography without overburdening average-risk populations with unnecessary procedures. This targeted allocation optimizes resource utilization and reduces patient anxiety associated with excessive testing.

Modern imaging techniques address specific limitations effectively. Digital breast tomosynthesis mitigates the tissue superposition problem inherent in two-dimensional mammography, leading to fewer false-positive results and more precise localization of abnormalities. When combined with ultrasound, the approach becomes particularly powerful for dense breasts, where mammography sensitivity declines. Magnetic resonance imaging, although resource-intensive, proves indispensable for dense tissue evaluation and treatment response monitoring, with dynamic contrast-enhanced sequences providing functional insights into vascularity and permeability that static images cannot capture. Positron emission tomography computed tomography, while less suited for primary screening, adds metabolic context during staging, helping differentiate indolent from aggressive lesions.

Biosensor platforms introduce molecular-level precision that imaging alone cannot achieve. Detection of specific markers in non-blood fluids such as saliva or sweat enables frequent, home-based monitoring that empowers patients and facilitates earlier intervention than annual clinic visits allow. The high sensitivity of these devices, often surpassing conventional thresholds, complements imaging by confirming suspicious findings or identifying occult disease in asymptomatic phases. Wearable technologies extend this capability further, transforming passive screening into active, continuous surveillance. Smart garments equipped with multiple sensor types generate longitudinal data streams that artificial intelligence algorithms analyze for subtle trends indicative of emerging pathology, potentially detecting changes months before traditional methods would register them.

Artificial intelligence integration stands out as a unifying force across modalities. By processing vast datasets rapidly and consistently, these systems reduce inter-observer variability, accelerate workflow in busy radiology departments, and support decision support tools that suggest optimal biopsy sites or risk categories. Multimodal fusion models that combine imaging features with biomarker profiles and clinical variables yield superior prognostic estimates, enabling personalized treatment planning from the diagnostic stage onward. Federated and self-supervised learning techniques promise to overcome data scarcity and privacy barriers, paving the way for globally scalable artificial intelligence solutions.

Early detection strategies must balance sensitivity with specificity to avoid overdiagnosis and overtreatment. Population screening programs tailored to age and risk demonstrate clear mortality reductions when implemented consistently, yet require ongoing evaluation to adapt to demographic shifts and technological improvements. In resource-constrained environments, hybrid models pairing low-cost ultrasound with biosensor kits or wearable prototypes offer viable alternatives to advanced imaging infrastructure. Public education campaigns that promote awareness of normal breast changes and encourage prompt reporting of anomalies further strengthen these efforts.

Potential drawbacks warrant acknowledgment. Radiation exposure from repeated mammography, though minimal, accumulates over decades, prompting exploration of radiation-free alternatives like microwave or optical imaging. Cost remains a barrier for magnetic resonance imaging and certain biosensors, necessitating subsidies or tiered access models. Standardization of wearable devices and artificial intelligence algorithms is incomplete, raising concerns about reproducibility across manufacturers and populations.

Ethical considerations include data security in continuous monitoring systems and equitable access to prevent widening health disparities.

Despite these challenges, the synergistic potential of combined approaches far outweighs individual limitations. Clinical pathways that sequence initial mammography with targeted ultrasound or magnetic resonance imaging, followed by biosensor confirmation and artificial intelligence-assisted interpretation, create robust diagnostic pipelines. Future refinements will likely incorporate large foundation models capable of interpreting multimodal inputs in real time, further streamlining care and enhancing outcomes. The discussion therefore supports a shift toward proactive, technology-augmented frameworks that align with patient preferences for comfort, convenience, and precision.

### Results

Synthesis of data from multiple studies reveals consistent improvements in detection metrics when modern methods are employed. Mammography combined with digital breast tomosynthesis achieves overall sensitivity rates of eighty-five to ninety-five percent, with particularly notable gains in dense breast subgroups where standalone mammography drops below seventy percent. Magnetic resonance imaging supplemental screening in high-risk cohorts increases cancer yield by twenty to thirty percent over mammography alone, identifying lesions at earlier stages with average sizes under one centimeter. Ultrasound integration further refines specificity, reducing unnecessary biopsies by ten to fifteen percent.

Biosensor evaluations demonstrate detection limits that enable identification of malignancies at preclinical phases. Electrochemical platforms targeting human epidermal growth factor receptor two and carbohydrate antigen fifteen-three consistently report limits below one picogram per milliliter in serum and even lower in saliva samples, correlating with ninety percent accuracy in blinded cohorts. Breath analysis via electronic nose technology yields classification accuracies of ninety-one to ninety-eight percent across hundreds of samples, with sensitivity reaching eighty-six percent and specificity ninety-seven percent. Sweat and urine volatile organic compound profiling, enhanced by convolutional neural network processing, distinguishes pre- and post-surgical states with over ninety percent precision, suggesting utility for longitudinal monitoring.

Wearable device trials indicate real-time detection of thermal anomalies or elasticity shifts corresponding to tumors as small as three millimeters, achieving eighty-eight percent accuracy in tissue stiffness assessment and up to ninety-five percent sensitivity in thermography-enhanced prototypes. Microwave sensor arrays embedded in garments detect

lesions exceeding five millimeters with sensitivities comparable to conventional ultrasound while eliminating radiation exposure.

Artificial intelligence models applied to imaging datasets produce area under the curve values of zero point nine or higher for lesion detection and zero point eight seven to zero point nine seven for molecular subtype classification. Segmentation performance reaches dice similarity coefficients of zero point eight to zero point nine seven, and multimodal fusion improves five-year risk prediction to zero point seven area under the curve. When artificial intelligence assists radiologists, recall rates decline while cancer detection rates remain stable or increase, demonstrating practical efficiency gains in clinical workflows.

Screening program outcomes show that adherence to age-specific protocols results in stage shifts: fifty to sixty percent of screen-detected cancers are localized versus twenty to thirty percent in symptomatic presentations. Survival projections for early-stage diagnoses approach ninety percent at five years, compared with significantly lower figures for advanced disease. Hybrid strategies incorporating biosensors and wearables in pilot communities report increased participation rates due to convenience, with preliminary detection yields matching or exceeding facility-based methods.

These synthesized results confirm that contemporary approaches not only elevate diagnostic accuracy but also expand accessibility and personalize care pathways. Quantitative gains in sensitivity, specificity, and early-stage capture rates provide strong empirical support for broader implementation.

### Conclusion

Breast cancer diagnosis has advanced significantly through the convergence of refined imaging techniques, molecular biosensor platforms, wearable monitoring solutions, and artificial intelligence support systems. Clinical approaches grounded in thorough history taking and risk stratification, paired with evidence-based early detection strategies, create comprehensive frameworks capable of identifying disease at its most treatable phases. The reviewed evidence demonstrates clear improvements in detection sensitivity, reduced false-positive burdens, and enhanced patient comfort compared with traditional methods alone.

Implementation of multimodal protocols tailored to individual risk profiles offers the greatest promise for mortality reduction and quality-of-life preservation. Continued research should prioritize large-scale prospective validation, cost-effectiveness analyses, and strategies to overcome barriers in low-resource settings. Collaboration among clinicians, technologists, and policymakers will be essential to translate these innovations into equitable, sustainable programs worldwide. Ultimately, the ongoing evolution of diagnostic

capabilities positions the medical community to transform breast cancer from a life-threatening condition into one that is routinely detected early and managed effectively, benefiting countless individuals and families.

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