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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

https://eurekaoa.com/index.php/5

ARTIFICIAL INTELLIGENCE -DRIVEN ADVANCES IN BREAST CANCER DETECTION, DIAGNOSIS AND PERSONALIZED TREATMENT

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Abstract:
Breast cancer remains the most prevalent malignancy and a leading cause of cancer-related mortality among women worldwide. Despite significant progress in screening and therapeutic strategies, challenges such as late-stage diagnosis, tumor heterogeneity, therapeutic resistance, and inter-observer variability continue to impede optimal clinical outcomes. Recent advancements in artificial intelligence (AI), particularly machine learning (ML), deep learning (DL), radiomics, and explainable AI (XAI), have demonstrated substantial potential in transforming breast cancer detection, diagnosis, prognosis, and treatment personalization. This review provides a comprehensive overview of current developments in AI-assisted breast cancer management, with a focus on image-based diagnostic modalities including mammography, ultrasound, magnetic resonance imaging, and automated breast ultrasound systems. Additionally, emerging applications of AI in biomarker identification, survival prediction, immunotherapy guidance, nanotechnology-based drug delivery, and resistance mitigation are discussed. While AI-driven approaches have shown promising improvements in diagnostic accuracy, efficiency, and decision support, challenges related to data heterogeneity, model generalizability, interpretability, and clinical integration persist. Addressing these limitations through large-scale

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

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validation, multidisciplinary collaboration, and standardized methodologies is essential for translating AI innovations into routine clinical practice and advancing precision oncology in breast cancer care.

Keywords: Breast cancer, artificial intelligence, deep Learning, machine learning, radiomics, computer-aided diagnosis, medical imaging, precision medicine, early detection.

Introduction

Breast cancer stands as the most prevalent form of cancer amongst females, constituting more than one-third of all cancer cases affecting women. It causes aberrant cell development, which can assault or spread to other sections of the body, perhaps leading to the patient's death. Based on research findings, timely detection can diminish the likelihood of mortality and enhance the quality of healthcare provided for the illness. However, current technologies can only identify cancer at an advanced stage. Consequently, there is a substantial demand for rapid and productive approaches to detecting breast cancer. Researchers are actively pursuing precise and timely methods for the diagnosis of breast cancer, aiming to achieve enhanced accuracy and early detection. Biosensor technology can allow for the speedy and accurate diagnosis of cancer-related cells, as well as a more sensitive and specialized technique for generating them. Additionally, numerous treatments for breast cancer are depicted such as herbal therapy, nanomaterial-based drug delivery, miRNA targeting, CRISPR technology, immunotherapy, and precision medicine. Early detection and efficient therapy are necessary to manage such a severe illness properly [10].

Breast Cancer (BC) is a major health issue in women of the age group above 45. Identification of BC at an earlier stage is important to reduce the mortality rate. Image-based noninvasive methods are used for early detection and for providing appropriate treatment. Computer-Aided Diagnosis (CAD) schemes can support

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ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

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radiologists in making correct decisions. Computational intelligence paradigms such as Machine Learning (ML) and Deep Learning (DL) have been used in the recent past in CAD systems to accelerate diagnosis. ML techniques are feature driven and require a high amount of domain expertise. However, DL approaches make decisions directly from the image. The current advancement in DL approaches for early diagnosis of BC is the motivation behind this review. This article throws light on various types of CAD approaches used in BC detection and diagnosis. A survey on DL, Transfer Learning, and DL-based CAD approaches for the diagnosis of BC is presented in detail. A comparative study on techniques, datasets, and performance metrics used in state-of-the-art literature in BC diagnosis is also summarized. The proposed work provides a review of recent advancements in DL techniques for enhancing BC diagnosis [2].

Breast cancer, the most prevalent malignant tumor among women, poses a significant threat to patients' physical and mental well-being. Recent advances in early screening technology have facilitated the early detection of an increasing number of breast cancers, resulting in a substantial improvement in patients' overall survival rates. The primary techniques used for early breast cancer diagnosis include mammography, breast ultrasound, breast MRI, and pathological examination. However, the clinical interpretation and analysis of the images produced by these technologies often involve significant labor costs and rely heavily on the expertise of clinicians, leading to inherent deviations. Consequently, artificial intelligence (AI) has emerged as a valuable technology in breast cancer diagnosis. Artificial intelligence includes Machine Learning (ML) and Deep Learning (DL). By simulating human behavior to learn from and process data, ML and DL aid in lesion localization reduce misdiagnosis rates, and improve accuracy. This narrative review provides a comprehensive review of the current research status of mammography using traditional ML and DL algorithms. It particularly highlights the latest advancements in DL methods for mammogram image analysis and offers insights into future development directions [7].

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Breast cancer is the most common forms of cancer and a leading cause of mortality in women. Early and correct diagnosis is, therefore, essential to save lives. The development of diagnostic imaging applied to the breast has been impressive in recent years and the most used diagnostic test in the world is mammography, a low-dose X-ray technique used for imaging the breast. In the first half of the 20th century, the diagnosis was in practice only clinical, with consequent diagnostic delay and an unfavorable prognosis in the short term. The rise of organized mammography screening has led to a remarkable reduction in mortality through the early detection of breast malignancies. This historical review aims to offer a complete panorama of the development of mammography and breast imaging during the last century. Through this study, we want to understand the foundations of the pillar of radiology applied to the breast through to the most modern applications such as contrast-enhanced mammography

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(CEM), artificial intelligence, and radiomics. Understanding the history of the development of diagnostic imaging applied to the breast can help us understand how to better direct our efforts toward an increasingly personalized and effective diagnostic approach. The ultimate goal of imaging applied to the detection of breast malignancies should be to reduce mortality from this type of disease as much as possible. With this paper, we want to provide detailed documentation of the main steps in the evolution of breast imaging for the diagnosis of breast neoplasms; we also want to open up new scenarios where the possible current and future applications of imaging are aimed at being more precise and personalized [16].

According to the WHO, in 2022, there were 2.3 million women diagnosed with breast cancer (BC) and 670,000 deaths globally. BC remains the leading cause of cancer-related mortality, with therapeutic resistance representing a significant barrier to effective treatment, particularly in aggressive subtypes like triple-negative breast cancer (TNBC). This review article discusses emerging strategies to overcome resistance by integrating precision oncology, nanotechnology-based drug delivery, and immune modulation. Resistance mechanisms-such as metabolic reprogramming, tumor heterogeneity, immune evasion, autophagy, and the role of cancer stem cells-are critically examined. We highlight cutting-edge nanoplatforms that co-deliver chemotherapeutics and immune stimulants with spatiotemporal precision, including sonodynamic and photothermal systems, ADCs, and targeted nanoparticles. Moreover, advances in tumor microenvironment (TME) modulation, photoimmunotherapy, and exosomal miRNA targeting offer promising avenues to enhance immunogenicity and therapeutic durability. The integration of molecular profiling with advanced computational approaches, including artificial intelligence and biomimetic models, holds significant promise for the future development of personalized resistance-mitigating interventions, though a detailed exploration is beyond the current scope. Collectively, these strategies reflect a paradigm shift from

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conventional monotherapies toward multifaceted, precision-guided treatment approaches. This review aims to provide a comprehensive overview of current innovations and propose future directions for overcoming drug resistance in BC [18].

Breast cancer, as one of the most common malignancies in women, exhibits complex and heterogeneous pathological characteristics across different subtypes. Triple-negative breast cancer (TNBC) and HER2-positive breast cancer are two common and highly invasive subtypes within breast cancer. The stability of the breast microbiota is closely intertwined with the immune environment, and immunotherapy is a common approach for treating breast cancer. Tertiary lymphoid structures (TLSs), recently discovered immune cell aggregates surrounding breast cancer, resemble secondary lymphoid organs (SLOs) and are associated with the prognosis and survival of some breast cancer patients, offering new avenues for immunotherapy. Machine learning, as a form of artificial intelligence, has increasingly been used for detecting biomarkers and constructing tumor prognosis models. This article systematically reviews the latest research progress on TLSs in breast cancer and the application of machine learning in the detection of TLSs and the study of breast cancer prognosis. The insights provided contribute valuable perspectives for further exploring the biological differences among different subtypes of breast cancer and formulating personalized treatment strategies [15].

Special histologic subtypes of breast cancer (BC) exhibit unique phenotypes and molecular profiles with diagnostic and therapeutic implications, often differing in behavior and clinical trajectory from common BC forms. Novel methodologies, such as artificial intelligence may improve classification. Genetic predisposition plays roles in a subset of cases. Uncommon BC presentations like male, inflammatory and pregnancy-related BC pose challenges. Emerging therapeutic strategies targeting genetic alterations or immune microenvironment are being explored [17].

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Breast cancer (BC) is the most common malignant tumor among women worldwide, posing a substantial threat to their health and overall quality of life. Consequently, for early-stage BC, timely screening, accurate diagnosis, and the development of personalized treatment strategies are crucial for enhancing patient survival rates. Automated Breast Ultrasound (ABUS) addresses the limitations of traditional handheld ultrasound (HHUS), such as operator dependency and inter-observer variability, by providing a more comprehensive and standardized approach to BC detection and diagnosis. Radiomics, an emerging field, focuses on extracting high-dimensional quantitative features from medical imaging data and utilizing them to construct predictive models for disease diagnosis, prognosis, and treatment evaluation. In recent years, the integration of artificial intelligence (AI) with radiomics has significantly enhanced the process of analyzing and extracting meaningful features from large and complex radiomic datasets through the application of machine learning (ML) and deep learning (DL) algorithms. Recently, AI-based ABUS radiomics has demonstrated significant potential in the diagnosis and therapeutic evaluation of BC. However, despite the notable performance and application potential of ML and DL models based on ABUS, the inherent variability in the analyzed data highlights the need for further evaluation of these models to ensure their reliability in clinical applications [8].
Breast cancer is one the main death causes for women worldwide, as 16% of the diagnosed malignant lesions worldwide are its consequence. In this sense, it is of paramount importance to diagnose these lesions in the earliest stage possible, in order to have the highest chances of survival. While there are several works that present selected topics in this area, none of them present a complete panorama, that is, from the image generation to its interpretation. This work presents a comprehensive state-of-the-art review of the image generation and processing techniques to detect Breast Cancer, where potential candidates for the image generation and processing are presented and discussed. Novel methodologies should consider the adroit integration of artificial intelligence-concepts and the

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categorical data to generate modern alternatives that can have the accuracy, precision and reliability expected to mitigate the misclassifications [4].

Background and Objective: Gynecological cancer is the most common cancer that affects women's quality of life and well-being. Artificial intelligence (AI) technology enables us to exploit high-dimensional imaging data for precision oncology. Tremendous progress has been made with AI radiomics in cancers such as lung and breast cancers. Herein, we performed a literature review on AI radiomics in the management of gynecological cancer. The included studies mainly focused on the current landscape of AI radiomics in the diagnosis, treatment, and prognosis of gynecological cancer. Key Content and Findings: A total of 128 studies were included, with 86 studies focusing on tumor diagnosis (n=23) and characterization (n=63), 15 on treatment response prediction, and 27 on recurrence and survival prediction. AI radiomics has shown potential value in tumor diagnosis and characterization, chemotherapy or chemoradiotherapy response evaluation, and prognosis (disease recurrence or metastasis, and survival) prediction. However, most included studies were single-center and retrospective. AI radiomics has been increasingly adopted in the management of gynecological cancer. Further validation in large-scale datasets is needed before clinical translation [3].

Background Breast cancer is the most common disease in women. Recently, explainable artificial intelligence (XAI) approaches have been dedicated to investigate breast cancer. An overwhelming study has been done on XAI for breast cancer. Therefore, this study aims to review an XAI for breast cancer diagnosis from mammography and ultrasound (US) images. We investigated how XAI methods for breast cancer diagnosis have been evaluated, the existing ethical challenges, research gaps, the XAI used and the relation between the accuracy and explainability of algorithms. Rayyan online platform detected duplicates, inclusion and exclusion of papers. Results This study identified 14 primary studies employing XAI for breast cancer diagnosis from mammography and US

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ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

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images. Out of the selected 14 studies, only 1 research evaluated humans' confidence in using the XAI system - additionally, 92.86% of identified papers identified dataset and dataset-related issues as research gaps and future direction [9].

Breast cancer (BC) is a predominant malignancy among women globally, with its etiology remaining largely elusive which are often limited by sample representation and processing time. Consequently, non-invasive imaging techniques such as mammography, ultrasound, and Magnetic Resonance Imaging (MRI) are indispensable for BC screening, diagnosis, staging, and treatment monitoring. Recent advancements in imaging technologies and artificial intelligence-driven radiomics have enhanced precision medicine by enabling early detection, accurate molecular subtyping, and personalized therapeutic strategies. Despite reductions in mortality through traditional treatments, challenges like tumor heterogeneity and therapeutic resistance persist. Immunotherapies, particularly PD-1/PD-L1 inhibitors, have emerged as promising alternatives. This review explores recent developments in BC imaging diagnostics and immunotherapeutic approaches, aiming to inform clinical practices and optimize therapeutic outcomes [11].

Artificial intelligence (AI) algorithms can be applied in breast cancer risk prediction and prevention by using patient history, scans, imaging information, and analysis of specific genes for cancer classification to reduce overdiagnosis and overtreatment. This scoping review aimed to identify the barriers encountered in applying innovative AI techniques and models in developing breast cancer risk prediction scores and promoting screening behaviors among adult females. Findings may inform and guide future global recommendations for AI application in breast cancer prevention and care for female populations. In the 11 included studies, a total of 39 barriers to AI applications in breast cancer risk prediction and screening efforts were identified. The most common barriers in the application of innovative AI tools for breast cancer prediction and improved

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screening rates included lack of external validity and limited generalizability (n = 6), as AI was used in studies with either a small sample size or datasets with missing data. Many studies (n = 5) also encountered selection bias due to exclusion of certain populations based on characteristics such as race/ethnicity, family history, or past medical history. Several recommendations for future research should be considered. AI models need to include a broader spectrum and more complete predictive variables for risk assessment. Investigating long-term outcomes with improved follow-up periods is critical to assess the impacts of AI on clinical decisions beyond just the immediate outcomes [19].

Breast cancer is a significant cause of cancer-related mortality in women worldwide. Early and precise diagnosis is crucial, and clinical outcomes can be markedly enhanced. The rise of artificial intelligence (AI) has ushered in a new era, notably in image analysis, paving the way for major advancements in breast cancer diagnosis and individualized treatment regimens. In the diagnostic workflow for patients with breast cancer, the role of AI encompasses screening, diagnosis, staging, biomarker evaluation, prognostication, and therapeutic response prediction. Although its potential is immense, its complete integration into clinical practice is challenging. Particularly, these challenges include the imperatives for extensive clinical validation, model generalizability, navigating the "black-box" conundrum, and pragmatic considerations of embedding AI into everyday clinical environments. In this review, we comprehensively explored the diverse applications of AI in breast cancer care, underlining its transformative promise and existing impediments. In radiology, we specifically address AI in mammography, tomosynthesis, risk prediction models, and including magnetic resonance imaging and ultrasound. In pathology, our focus is on AI applications for pathologic diagnosis, evaluation of biomarkers, and predictions related to genetic alterations, treatment response, and prognosis in the context of breast cancer diagnosis and treatment. Our discussion underscores the transformative

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potential of AI in breast cancer management and emphasizes the importance of focused research to realize the full spectrum of benefits of AI in patient care [1].
Cervical cancer (CC) is a malignant gynaecological tumour that poses a serious threat to the lives of patients worldwide. CC is the second-most common-cancer in women located in developing countries, following breast cancer. Therefore, given the persistently high incidence and mortality rates of CC, it is necessary to explore better diagnostic and treatment methods for this disease so that prevention and treatment strategies can be improved. As a science that develops computer programs to simulate, enhance, and extend human behaviours, artificial intelligence (AI) offers new possibilities for achieving this goal. In recent years, AI has shown considerable potential for accurately screening, diagnosing and treating cancer. For CC, the rapid development of AI provides new possibilities for performing early screening and achieving precise clinical diagnoses and treatments. This review is focused on the current state of research regarding the application of AI for the early screening, precise clinical diagnosis, and treatment of CC, as well as the challenges we will face in the future [20].
Breast cancer (BC), as a leading cause of cancer mortality in women, demands robust prediction models for early diagnosis and personalized treatment. Artificial Intelligence (AI) and Machine Learning (ML) algorithms offer promising solutions for automated survival prediction, driving this study's systematic review and meta-analysis. Original articles applying ML algorithms for BC survival prediction using clinical data were included. The quality of studies was assessed via the Qiao Quality Assessment tool. Hybrid models, combining traditional and modern ML techniques, were mostly considered to predict survival rates (40.62%). Supervised learning was the dominant ML paradigm (75%). Notably, 81.25% of studies relied on internal validation, primarily using K-fold cross-validation and train/test split strategies. The findings underscore the significant potential of AI-based algorithms in enhancing the accuracy of BC survival predictions [12].

Breast cancer remains the most diagnosed cancer in women. Advances in medical imaging modalities and technologies have greatly aided in the early detection of breast cancer and the decline of patient mortality rates. However, reading and interpreting breast images remains difficult due to the high heterogeneity of breast tumors and fibro-glandular tissue, which results in lower cancer detection sensitivity and specificity and large inter-reader variability. In order to help overcome these clinical challenges, researchers have made great efforts to develop computer-aided detection and/or diagnosis (CAD) schemes of breast images to provide radiologists with decision-making support tools. Recent rapid advances in high throughput data analysis methods and artificial intelligence (AI) technologies, particularly radiomics and deep learning techniques, have led to an exponential increase in the development of new AI-based models of breast images that cover a broad range of application topics. In this review paper, we focus on reviewing recent advances in better understanding the association between radiomics features and tumor microenvironment and the progress in developing new AI-based quantitative image feature analysis models in three realms of breast cancer: predicting breast cancer risk, the likelihood of tumor malignancy, and tumor response to treatment. The outlook and three major challenges of applying new AI-based models of breast images to clinical practice are also discussed. Through this review we conclude that although developing new AI-based models of breast images has achieved significant progress and promising results, several obstacles to applying these new AI-based models to clinical practice remain. Therefore, more research effort is needed in future studies [13].

The advent of artificial intelligence (AI) represents a real game changer in today's landscape of breast cancer imaging. Several innovative AI-based tools have been developed and validated in recent years that promise to accelerate the goal of real patient-tailored management. Numerous studies confirm that proper integration of AI into existing clinical workflows could bring significant benefits to women, radiologists, and healthcare systems. The AI-based approach has proved

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particularly useful for developing new risk prediction models that integrate multi-data streams for planning individualized screening protocols. Furthermore, AI models could help radiologists in the pre-screening and lesion detection phase, increasing diagnostic accuracy, while reducing workload and complications related to overdiagnosis. Radiomics and radiogenomics approaches could extrapolate the so-called imaging signature of the tumor to plan a targeted treatment. The main challenges to the development of AI tools are the huge amounts of high-quality data required to train and validate these models and the need for a multidisciplinary team with solid machine-learning skills. The purpose of this article is to present a summary of the most important AI applications in breast cancer imaging, analyzing possible challenges and new perspectives related to the widespread adoption of these new tools [5].

Breast cancer (BCA) remains the most prevalent cancer globally and the leading cause of cancer-related mortality among women, with rising incidence rates driven by genetic, lifestyle, and environmental factors. Early detection through precise screening is essential to improve prognosis and survival; yet, challenges persist, especially in resource-limited areas. Recent advances in Artificial Intelligence (AI), particularly machine learning and deep learning algorithms, have illustrated significant potential to enhance breast cancer screening, diagnosis, and treatment personalization. This review highlights the multifaceted role of AI in BCA management, encompassing its applications in image-based screening modalities, genomic and immunologic profiling, and drug discovery. AI-driven approaches offer diagnostic accuracy, cost-effectiveness, time-saving, and individualized treatment regimens. Despite promising developments, further research is crucial to overcome current challenges and regulatory hurdles in clinical settings. This article highlights the positive aspects of AI technologies in advancing BCA care and the importance of continued interdisciplinary research to optimize their implementations in breast cancer workflows [6].

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Conclusion:

Breast cancer continues to pose a significant global health burden, underscoring the critical need for early detection, accurate diagnosis, and effective personalized treatment strategies. Advances in artificial intelligence have emerged as a transformative force across the entire breast cancer care continuum, from screening and lesion detection to prognostic modeling and therapeutic response prediction. AI-driven methodologies, particularly deep learning and radiomics, have demonstrated superior performance in analyzing complex medical imaging data while reducing diagnostic variability and clinician workload. Furthermore, the integration of AI with emerging therapeutic paradigms-including immunotherapy, nanomedicine, and precision oncology-offers promising avenues to address tumor heterogeneity and treatment resistance.

Despite these advancements, the clinical translation of AI-based solutions remains constrained by challenges such as limited external validation, lack of interpretability, data imbalance, and ethical concerns. Future research should prioritize large-scale, multicenter studies, explainable AI frameworks, and robust regulatory pathways to ensure reliability and clinical acceptance. Ultimately, the synergistic integration of artificial intelligence with advanced imaging, molecular profiling, and personalized treatment strategies holds substantial promise for improving survival outcomes and quality of life for patients with breast cancer.

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