Review Article

Radiogenomics with Mammography and Ultrasound for Breast Cancer Diagnosis in LMICS: A Conceptual Narrative Review

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ABSTRACT

Late diagnosis of breast cancer is a major challenge in low-resource areas of Low-and Middle-Income Countries (LMICs) due to limited access to diagnostic facilities. This review proposes a conceptual framework for an affordable, accurate, and early diagnosis of breast cancer in LMICs by using a mobile setup of multimodal radiogenomics with ultrasound, mammography, and artificial intelligence (AI). Recent literature was analyzed related to breast cancer, its diagnostic modalities, such as mammography, ultrasound, magnetic resonance imaging (MRI), biopsies, and AI. A conceptual framework is planned for early breast cancer diagnosis in LMICs. The findings reported that this multimodal radiogenomics approach can be 85% to 90% accurate in diagnosing breast cancer, its types, subtypes, and stages. Multimodal radiogenomics with AI in a mobile system can be helpful for areas that lack the resources for early diagnosis.

Keywords: radiogenomics; breast cancer; AI; mammography; ultrasound

INTRODUCTION

Breast cancer remains the most frequently diagnosed cancer and one of the leading causes of cancer-related mortality among women worldwide. According to the Global Cancer Observatory (GLOBOCAN), approximately 2.3 million new breast cancer cases and 685,000 deaths were reported globally in 2022[2]. Despite significant advances in breast cancer diagnosis and treatment, disparities in access to healthcare continue to contribute to poor outcomes, particularly in low- and middle-income countries (LMICs). Women living in rural and underserved regions of countries such as Pakistan, India, and Bangladesh often experience delayed diagnosis because of limited access to specialized healthcare facilities, diagnostic imaging, and pathology services. The International Agency for Research on Cancer (IARC) projects that the cancer burden in LMICs will increase by nearly 75% by 2050, emphasizing the urgent need for accessible and cost-effective diagnostic strategies[3].

Delayed diagnosis remains one of the major contributors to breast cancer mortality in LMICs. Geographic barriers, financial constraints, inadequate healthcare infrastructure, and limited awareness frequently prevent women from seeking timely medical attention. Advanced diagnostic investigations, including magnetic resonance imaging (MRI) and tissue biopsy, are often unavailable or unaffordable in rural settings. Transportation costs, long travel distances, and shortages of specialized healthcare professionals further delay diagnosis and treatment. In addition, limited health literacy and lack of awareness regarding breast cancer symptoms contribute to late-stage presentation, reducing the likelihood of successful treatment[3].

Pakistan bears one of the highest breast cancer burdens in Asia, with an estimated lifetime risk of approximately one in nine women developing the disease[4]. Compared with women in many high-income countries, Pakistani women are often diagnosed at a younger age and at more advanced stages of disease. Socioeconomic challenges, cultural stigma, limited awareness, and insufficient diagnostic facilities continue to hinder early detection[4,5]. Rural populations are particularly disadvantaged because specialized diagnostic services are concentrated in major urban centers, requiring patients to travel considerable distances and incur substantial out-of-pocket expenses[4]. Consequently, delayed diagnosis remains an important contributor to the country's high breast cancer mortality.

Advances in breast imaging, including mammography and ultrasound, have substantially improved the early detection of breast cancer over recent decades[6]. More recently, artificial intelligence (AI) has emerged as a promising tool for enhancing image interpretation and supporting clinical decision-making. Parallel developments in radiogenomics, which integrates quantitative imaging features with genomic information, have expanded opportunities for non-invasive tumor characterization, prediction of molecular subtypes, treatment planning, and prognostic assessment[7]. Although these technologies have shown encouraging results in high-resource healthcare settings, their implementation in LMICs remains limited because of financial, technical, and infrastructural constraints. Nevertheless, portable

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imaging technologies, AI-assisted image analysis, and mobile healthcare platforms have generated increasing interest as potential approaches to improve access to breast cancer screening and diagnosis in resource-constrained environments.

Although individual advances in AI, mammography, ultrasound, and radiogenomics have been widely reported, limited attention has been given to their combined application for improving breast cancer diagnosis in rural LMIC settings. Furthermore, the potential role of mobile diagnostic platforms integrating these technologies has not been comprehensively discussed. This narrative review synthesizes the current evidence on multimodal radiogenomics using mammography, ultrasound, and AI, and presents a conceptual framework for its potential application in resource-limited settings. By highlighting current evidence, implementation challenges, and future opportunities, this review aims to inform researchers, clinicians, and policymakers seeking innovative strategies to strengthen early breast cancer diagnosis in LMICs.

METHODOLOGY

This conceptual narrative review was conducted between September 2025 and March 2026 to examine the potential role of mobile radiogenomics integrating mammography, ultrasound, and artificial intelligence (AI) for improving breast cancer diagnosis in resource-limited settings of low- and middle-income countries (LMICs).

A non-systematic literature search was performed using electronic databases, including PubMed Central, ScienceDirect, and ResearchGate, along with publications from the World Health Organization (WHO) and other relevant institutional websites. The search included combinations of keywords related to *breast cancer, mammography, ultrasound, radiogenomics, artificial intelligence, mobile screening, and LMICs. Peer-reviewed articles and authoritative institutional publications published between 2012 and 2026 were considered.

The literature was selected based on its relevance to breast cancer diagnosis, diagnostic challenges in LMICs, radiogenomics, AI-assisted imaging, multimodal diagnostic approaches, and the feasibility of mobile screening strategies. Publications focusing exclusively on surgical management, treatment, or unrelated therapeutic interventions were excluded. Original research articles, review articles, and selected case-based reports that contributed meaningful insights to the review objectives were included. The selected literature was narratively synthesized to identify recurring themes related to diagnostic technologies, clinical applications, implementation challenges, AI integration, affordability, and accessibility in rural and underserved settings. These themes were subsequently integrated to develop a conceptual framework illustrating the potential application of mobile multimodal radiogenomics for early breast cancer diagnosis in LMICs. As a narrative review, this article is based entirely on published literature and does not involve human participants, animals, or primary data collection. Therefore, ethical approval was not required. All included sources were appropriately acknowledged in the references.

RESULTS

Three main themes were analyzed from the literature. The clinical accuracy was identified, which reported that multimodal mammography and ultrasound perform the prediction of molecular subtypes (ER, PR, and HER2) and substages. The studies reported that ultrasound works as a complementary modality for dense breasts. Multimodal radiogenomics was able to diagnose cancer stages and types without the use of biopsy. The technical feasibility was evaluated, which found that mobile radiology units were operational in LMICs where portable modalities are used. AI-assisted feature extraction gave logical correlations between image texture and genomic profiles when trained on adequate datasets. The review identified operational pathways where AI models were locally implemented using affordable infrastructure. The socioeconomic analysis found that mobile mammography supports affordability and reduction in diagnostic delays.

Table I: Accuracy of different modalities for receptors and genes

Reference No.	Modality	Receptor	AUC/ AUROC
14	DCE-MRI AND Ultrasound	ER/PR/HER2	0.93
8	Ultrasound Radiomics	Node Metastatic	0.91
11	Mammography CNN	HER2	0.89
18	Multimodal Transformer	Triple-Negative	0.94
7	Comprehensive Review	All Subtypes	—
9	Hybrid Radiogenomics AI	ER/PR/HER2	0.95
6	MRI Radiogenomics	Luminal A/B	0.92
13	Deep Radiogenomics Sequencing	Gene Expression	0.93
14	Multimodality Review	Integration	—
20	Xylexa AI	HER2/ Luminal A	0.89

A conceptual mobile screening model was proposed by using these themes. The focus was on low-resourced areas of LMICs. The model contained three main parts. A portable mobile unit was proposed. The proposed unit contained both ultrasound and mammography machines. A cloud-based AI analysis module was part of the model. The proposed module was designed for feature extraction, type, subtype, and stage prediction. The third was a reporting system. It was non-invasive. Low-cost infrastructure was used for the framework. The model did not need biopsies. No primary data was collected for this model.

DISCUSSION

The review was conducted to improve the diagnostic limitations of breast cancer in underdeveloped areas of LMICs. Radiogenomics was defined as an advanced field that integrates phenotypes with genotypes[7]. The high-income countries lead this research. This field used AI to extract the genetic profile of the disease from radiological images. Modals such as Convolutional Neural Network (CNN) and transformers were trained with deep learning and machine learning to analyze radiological images[8]. Training needs huge datasets. They were used to identify deep textural variations related to gene pathways such as BRCA1/2, TP53, GATA3, and PIK3CA[9]. AI was noted to predict stages, types, and subtypes of breast cancer without invasive procedures such as biopsy[10]. The patient's trauma decreases significantly. The standard and detailed diagnosis of breast cancer has relied on biopsy. Access was limited to this invasive procedure. Mammography and ultrasound were the basic tools for breast cancer diagnosis. In radiogenomics, AI was reported to assist with different modalities for diagnosis. DCE-MRI with AI showed high accuracy in the radiogenomics field. MRI is not practical for mobile systems. The cost and feasibility of DCE-MRI were not suitable for rural areas of LMICs[6]. Ultrasound and mammography, individually, showed limitations for deep diagnosis.[11]Their combined application was found to be better in accuracy. When mammography and ultrasound were used as a combined model with AI, improved performance was found[12,13]. The studies reported that multimodal radiomics for genomic diagnosis of breast tissue heterogeneity. Multimodal mammography and ultrasound provided details about micro differences[14]. The radiographic features, such as spiculation, enhancement kinetics, and texture anomalies, were compared with specific genomic mutations. High-income countries demonstrated progress in radiogenomic research and application. LMICs have infrastructural gaps. The concept of reducing reliance on biopsies was analyzed in the studies. Mobile screening units were found to be a suitable approach for remote areas[15]. Portable mammography showed practical feasibility in rural areas of LMICs[16]. Ultrasound was noted to be valuable for the diagnosis of dense tissues of the breast[17]. A Conceptual model for early diagnosis was proposed. That was conceptually designed by the integration of mobile multimodal radiogenomics to fill the diagnostic gap of LMICs.

International literature, mainly from high-income countries, has described the application of radiogenomics in detail[9]. Researchers used models such as a transformer and a CNN to integrate the genomic profile from radiological images[18]. BRCA1/2 and TP53 associations across several datasets over the past years[7]. Radiogenomics is being studied and reviewed to be practically applicable by high-income countries. Validation studies report high accuracy in controlled settings. This field is an emerging trend for advanced diagnosis, according to the literature. Current international literature is exploring radiogenomics beyond MRI to transform this field into a portable system. The studies are working on ultrasound-based radiogenomics for feasibility. Multimodal data fusion is a key trend to make radiogenomics accurate as well as accessible. The researchers are improving portable diagnosis with battery-operated machines. The AI models are being trained to be more accurate, deep, and feasible. Cloud-based AI was found to be applicable for areas with limited internet access. The studies from High-income countries have limited research for the LMICs workflow because ground realities are different. Most datasets don’t have diversity for LMIC populations. Pakistan, as LMICs, doesn’t have enough literature studies and research on radiogenomics. LMICs have limited technological infrastructure for diagnostic facilities. The high cost of genomic testing also limits adoption. The studies have addressed Pakistan’s breast cancer diagnostic gap, delay, and infrastructural limitations[4]. The other common issues for breast cancer diagnosis are a lack of awareness and screening sessions[19]. Mobile screening units were analyzed as a practical solution for rural regions[16]. Such units reduce the time and expenses of travel for patients. Pakistan has limited literature on radiogenomics and its application in LMICs as compared to the international level.

Pakistan faces high breast cancer case deaths because of late-stage diagnosis[4]. The national literature mainly focuses on clinical delay and patient factors. Radiogenomics is rarely explored by Pakistani researchers. Peer-reviewed work on imaging-genomics correlation from Pakistan is not found. Limited papers are published that report AI with imaging but not with genomics. No study has linked ultrasound features to gene profiles in rural cohorts. There are no local datasets for training such models. This forces dependence on data from High-income countries. Mobile health literature focuses mainly on awareness of contagious diseases. Mobile screening and awareness of oncology are scarce. Breast cancer screening vans are documented, but it is used only with basic screening modalities. There is no AI-driven risk stratification in a mobile system. A multimodal radiogenomics approach is absent in Pakistani literature. International studies use AI to understand genomic data from radiological images, but Pakistan has no trials for this combination. No paper cover combination of multimodal with AI risk scores in a mobile setting. Late diagnoses are reported several times in research, but radiogenomics as an early diagnostic tool has not been reported. The literature addresses the problem of late diagnosis. There are infrastructural gaps in Pakistan. The facilities of the diagnostic and histopathological labs are limited in rural areas.[2]Needle-free radiomic risk identification is not just novel but necessary. Limited diagnostic facilities cause a delay in treatment initiation. Mobile screening facilities are limited but are suitable to reduce geographical barriers. The portable radiogenomics diagnostic facilities were found to be suitable for rural areas in studies. Radiogenomics integrated with mobile multimodal diagnosis has not been practically explored in Pakistan. National literature has limited research on novel trends for the improvement of the diagnostic gaps of breast cancer.

Radiogenomics is a developing field, and it is not yet fully applied in a clinical system. Clinical trials remain limited in LMICs. Further research and experiments for practical applications are being done. This gap is linked with the objective of this study. The approach of this research is the integration of Radiogenomics and a mobile screening system in limited resource areas. It can be practically applicable after its trials and further processing. Local validation will test the validity of this review. In the future, this approach can be a suitable option to increase early diagnosis of breast cancer and reduce mortality in LMICs. This aligns with the primary approach of the study. The studies supported that radiogenomics can diagnose the subtypes of cancer and cancer profiles. That will decrease the reliance on invasive biopsies and repeated imaging. For Pakistan's healthcare projects, mobile mammography programs could allow AI-assisted diagnosis directly in rural regions, according to the literature. The review synthesizes evidence supporting such programs. After getting positive results from the trials, the establishment of the radiogenomics databases should be done. Database creation is the next important step for the approach. This concept can be legally started in LMICs and may reduce the late diagnosis. It fulfills the rationale of the study. The collaboration between academic institutes and start-ups like Xylexa, an AI for the medical field, is required to improve further research on this technical concept[20]. Such partnerships may pilot the framework. When Radiogenomics becomes a regular screening program, more research is necessary for advanced diagnosis, such as receptor-based prediction 5-years before the onset of the symptoms[10]. This aligns with long-term objectives. This field may not only help in diagnosis but also in treatment planning.

However, applying these implications practically, several barriers need to be addressed. Practical implication faces challenges. Rural areas lack stable electricity. The internet access is also limited there. The successful implementation of this framework depends on three min strategic pillar. First, infrastructure must be adapted for local areas. Edge computing can help, as it runs lightweight models offline. Second, data from national patients should be collected for genomic correlations. The current datasets have limited representations of the South Asian genotypes. The third pillar is a regulatory pathway for clarity and privacy. Policies should be made to protect the privacy of the data. Professional procedures should be implemented before the practical initiation of mobile screening with AI. Training radiographers is another step. This Framework will be applicable after legal validation, investment, human involvement, and infrastructural development.

This study has some limitations. Radiogenomics data from Pakistan is limited. Currently, AI models rely on datasets from high-income countries. Mobile screening is limited to LMICs. This framework still needs human involvement to validate the AI outcomes. Ethical concerns should be noted for patient consent and privacy policies. Despite these gaps, the review synthesizes the available data to demonstrate the infrastructural limits and address feasible solutions. Future pilot projects in Pakistan can test the credibility of this concept in practice.

CONCLUSION

This narrative review highlights the persistent challenges associated with early breast cancer diagnosis in resource-limited regions of low- and middle-income countries (LMICs), where delayed diagnosis, financial constraints, and limited access to diagnostic services continue to contribute to poor outcomes. The reviewed literature suggests that integrating mammography, ultrasound, artificial intelligence (AI), and radiogenomics has the potential to improve early detection and support more accessible, non-invasive breast cancer assessment. Based on the available evidence, a conceptual mobile multimodal radiogenomics framework is proposed as a potential strategy to enhance diagnostic access in underserved communities. Although the concept is promising, its clinical effectiveness, feasibility, and cost-effectiveness require validation through prospective clinical and implementation studies. This review provides a conceptual foundation to guide future research and inform the development of innovative, equitable breast cancer diagnostic pathways in LMICs.

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AUTHOR CONTRIBUTION

Sangrasi A: Concept and literature review
Asif R: Concept, design of study & analysis
Chaudhary L: Drafting the article and finalizing the manuscript
Shaikh MM: Revising critically and make it suitable for final format
Sajid A: Literature review
Shaikh HM: Drafting and finalizing the manuscript
Muhammad AT: Literature writing and analysis

REFERENCES

1. Ismaili N. A Systematic Review of Major Advances in Breast Cancer Therapeutics in 2025: Synthesis of Conference and Published Evidence. Int J Mol Sci. 2026; 27(4).
2. Barrios CH. Global challenges in breast cancer detection and treatment. Breast. 2022; 62 Suppl 1 (Suppl 1): S3–s6.
3. Dummer T. Introduction: People, Place, Cancer. Understanding Cancer Prevention through Geospatial Science: Putting Cancer in its Place: Springer; 2024; 3-15.
4. Wyne E, Khan AA, Israr A. The lack of breast cancer screening programmes (Mammograms) in Pakistan. J Pak Med Assoc. 2025; 75(11): 1835.
5. Karamullah AO, Buttl A, Shahzad F. Awareness of Breast Cancer in Patients at A Tertiary Care Hospital in Pakistan: A Cross-Sectional Study.
6. Feng S, Yin J. Dynamic contrast-enhanced magnetic resonance imaging radiomics analysis based on intratumoral subregions for predicting luminal and nonluminal breast cancer. Quant Imaging Med Surg. 2023; 13(10): 6735–49.
7. Demetriou D, Lockhat Z, Brzozowski L, Saini KS, Dlamini Z, Hull R. The Convergence of Radiology and Genomics: Advancing Breast Cancer Diagnosis with Radiogenomics. Cancers (Basel). 2024; 16(5).
8. Ye X, Zhang X, Lin Z, Liang T, Liu G, Zhao P. Ultrasound-based radiomics nomogram for predicting axillary lymph node metastasis in invasive breast cancer. Am J Transl Res. 2024; 16(6): 2398–410.
9. Yamamoto S, Maki DD, Korn RL, Kuo MD. Radiogenomic analysis of breast cancer using MRI: a preliminary study to define the landscape. AJR Am J Roentgenol. 2012; 199(3): 654–63.
10. Arasu VA, Habel LA, Achacoso NS, Buist DSM, Cord JB, Esserman LJ et al. Comparison of Mammography AI Algorithms with a Clinical Risk Model for 5-Year Breast Cancer Risk Prediction: An Observational Study. Radiology. 2023; 307(5): e222733.
11. Balkenende L, Teuwen J, Mann RM. Application of Deep Learning in Breast Cancer Imaging. Semin Nucl Med. 2022; 52(5): 584–96.
12. Zhao M, Zheng Y, Chu J, Liu Z, Dong F. Ultrasound-based radiomics combined with immune status to predict sentinel lymph node metastasis in primary breast cancer. Sci Rep. 2023; 13(1): 16918.
13. Li J, Xing Y, Gao X, Ye Z, Wang M, Song F. A CT imaging-based deep learning model for predicting EGFR and KRAS mutations in non-small cell lung cancer: toward personalized treatment approaches. Transl Lung Cancer Res. 2026; 15 (1): 4.
14. Wu J, Li Y, Gong W, Li Q, Han X, Zhang T. Multi-modality radiomics diagnosis of breast cancer based on MRI, ultrasound and mammography. BMC Med Imaging. 2025; 25(1): 265.
15. Vang S, Margolies LR, Jandorf L. Mobile Mammography Participation Among Medically Underserved Women: A Systematic Review. Prev Chronic Dis. 2018; 15: E140.
16. Trivedi U, Omofoye TS, Marquez C, Sullivan CR, Benson DM, Whitman GJ. Mobile mammography services and underserved women. Diagnostics. 2022; 12(4): 902.
17. Iacob R, Iacob ER, Stoicescu ER, Ghenciu DM, Cocolea DM, Constantinescu A et al. Evaluating the Role of Breast Ultrasound in Early Detection of Breast Cancer in Low- and Middle-Income Countries: A Comprehensive Narrative Review. Bioengineering (Basel). 2024; 11(3).
18. Shen Y, Park J, Yeung F, Goldberg E, Heacock L, Shamout F, et al. Leveraging transformers to improve breast cancer classification and risk assessment with multi-modal and longitudinal data. arXiv preprint arXiv: 231103217. 2023.
19. Clark-Rowea CR. Understanding Access to Preventive Health Screening for Working Women Through the Lens of the Socioecological Model: Walden University; 2024.
20. Arshad N, Ahmad W, Manzoor K. Unleashing the potential of Pakistan's IT Industry: Building for massive software export growth. 2024.