



The Role of Imaging Modalities in Determining Surgical Management of Breast Cancer: A Literature Review

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Abstract

Breast cancer is one of the most common malignancies among women and remains a major cause of morbidity and mortality worldwide. Because breast cancer may develop without obvious symptoms in its early stages, accurate imaging assessment is essential to support early detection, disease staging, and appropriate treatment planning. Imaging modalities such as mammography, ultrasonography, magnetic resonance imaging (MRI), dynamic contrast-enhanced MRI (DCE-MRI), and artificial intelligence-based imaging technologies play an important role in evaluating tumor size, lesion characteristics, disease extent, multifocality, and treatment response. This study aimed to examine the role of imaging modalities in determining surgical management for breast cancer. This study employed a narrative literature review with PRISMA-guided article selection. Literature was collected through searches in PubMed, Google Scholar, Garuda, and other relevant scientific databases using selected keywords, including breast cancer, imaging modalities, mammography, ultrasonography, magnetic resonance imaging, MRI, DCE-MRI, surgical management, and surgical planning. Based on the screening process, 11 articles consisting of 4 national and 7 international journals were included in the review. The findings indicate that mammography is important for early detection, ultrasonography supports lesion characterization and clinical decision-making, while MRI and DCE-MRI provide more detailed information regarding tumor extent, local staging, multifocal lesions, and response to neoadjuvant therapy. Artificial intelligence-based imaging also shows potential in improving diagnostic accuracy and supporting individualized surgical planning. Therefore, imaging modalities are not only diagnostic tools but also strategic components in determining the type and extent of surgical treatment in breast cancer patients.

Introduction

A tumor is a swelling in or on the body caused by abnormal cell growth. Tumors can be malignant or benign. A tumor is a pathological disorder of cell growth characterized by excessive, uncontrolled, and abnormal cell proliferation that can be solid or fluid-filled (Jain & Pandey, 2022; Bisoyi, 2022; Kumar et al., 2025). When tumor cell growth is confined to its original location and is physically normal, it is a benign tumor. However, if the abnormal cells

continue to grow uncontrollably, it is called a malignant tumor or cancer (Singh & Roghini, 2023). Breast cancer is a disease in which abnormal cells in the breast grow uncontrollably, forming a tumor. If the tumor is not treated properly, the tumor can spread throughout the body and be fatal (Brown et al., 2023). One of the clinical symptoms in cancer patients is pain, which can affect approximately 66% of cancer sufferers (Boire et al., 2024; Wang et al., 2025; Nowak et al., 2022).

Breast cancer is one of the most frequently diagnosed cancers and the fifth leading cause of cancer death worldwide, surpassing lung cancer, with an estimated 2.3 million cases and 685,000 deaths in 2020, which is expected to reach 4.4 million by 2070. Breast cancer in women accounts for approximately 24.5% of all cancer cases and 15.5% of cancer deaths, ranking first in both incidence and mortality in most countries worldwide in 2020 (Cao et al., 2024; Kim et al., 2025; Kang et al., 2023).

Risk factors closely associated with an increased incidence of breast cancer include female gender, age >50 years, family and genetic history (carrier of BRCA1, BRCA2, ATM, or TP53 (p53) gene mutations), previous breast disease (DCIS in the same breast, LCIS, high density on mammography), history of early menstruation/menarche (<12 years) or late menopause (>55 years), reproductive history (no children and no breastfeeding), hormonal changes, obesity, alcohol consumption, history of chest wall radiation, and environmental factors (Zafar et al., 2022).

The most common early signs and symptoms of breast cancer are lumps or thickening in the breast. Advanced signs and symptoms of breast cancer include sunken skin, nipple retraction or deviation, pain, tenderness or palpation, and nipple discharge. Thickened skin with prominent pores resembling an orange peel and/or ulceration of the breast are advanced signs of breast cancer. Signs and symptoms of widespread metastases include pain in the shoulder, waist, lower back, or pelvis, persistent stones, anorexia or weight loss, digestive disorders, dizziness, blurred vision, and headaches (Liu, 2024).

Breast self-examination, or BSE, is a test performed to detect breast cancer in its early stages, allowing early treatment to extend the life expectancy of breast cancer patients (Conte et al., 2023; Oglat et al., 2024; Naz et al., 2024). BSE is a simple test performed by every woman to detect lumps or other breast abnormalities.

Breast cancer generally develops silently and is often detected through routine screening, especially in Western countries (Lemij et al., 2023; Jahan, 2026; Akbari et al., 2024). Without screening, breast cancer is usually detected when it appears as a palpable lump in the breast. Mammography is the most common modality used for breast cancer screening and diagnosis. Abnormal findings on mammography include masses, calcifications, or distortion of breast tissue architecture. Breast imaging findings are classified based on the Breast Imaging Reporting and Data System (BI-RADS), which links imaging findings to the probability of malignancy and provides general management strategy recommendations (Merjane et al., 2024; Ozsahin et al., 2024). BI-RADS categories range from 0 to 6. Routine laboratory tests and imaging to detect systemic disease are not recommended for operable breast cancer if there are no symptoms suggestive of metastasis. However, if suspicious symptoms are present, a brain MRI, chest CT scan, bone scan, or abdominal and pelvic CT scan may be performed as indicated.

Based on this description, it can be concluded that breast cancer is a highly complex malignancy that requires multidisciplinary treatment, particularly in determining appropriate surgical management. Imaging modalities such as mammography, ultrasound, and magnetic resonance imaging (MRI), including advances in artificial intelligence-based technology, play a critical role in assessing tumor characteristics, determining disease stage, and detecting lesion extent and multifocality (Huang et al., 2025; Hussain et al., 2025; Bagheriye & Kwisthout,

2025; Ali et al., 2025). Therefore, this study aims to determine the role of imaging modalities in determining surgical management for breast cancer, thus providing a basis for more accurate, effective, and individualized treatment planning tailored to the patient's condition.

Methods

This study employed a narrative literature review with PRISMA-guided article selection to examine the role of imaging modalities in determining surgical management for breast cancer. This approach was used because the study aimed to synthesize findings from previous studies related to imaging modalities and their contribution to clinical decision-making, rather than conducting a statistical meta-analysis. The review focused on imaging modalities commonly used in breast cancer assessment, including mammography, ultrasonography, magnetic resonance imaging (MRI), dynamic contrast-enhanced MRI (DCE-MRI), radiomics, and artificial intelligence-based imaging technologies (Chaddad et al., 2023; Arslan et al., 2024).

The literature search was conducted through several scientific databases, namely PubMed, Google Scholar, and Garuda. The search was carried out using selected keywords relevant to the research topic, including “breast cancer,” “imaging modalities,” “mammography,” “ultrasonography,” “magnetic resonance imaging,” “MRI,” “DCE-MRI,” “radiomics,” “artificial intelligence,” “surgical management,” and “surgical planning.” These keywords were used individually and in combination to identify articles discussing the role of imaging in breast cancer diagnosis, staging, tumor characterization, assessment of lesion extent, evaluation of treatment response, and planning of surgical treatment.

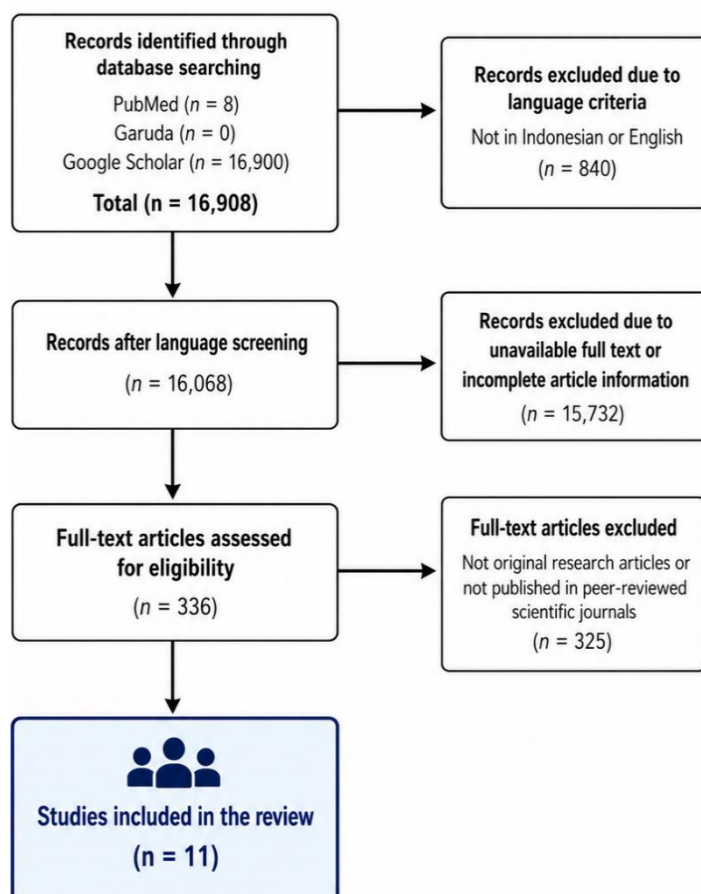


Figure 1. PRISMA Flowchart of Research Article: The Role of Imaging Modalities in Determining Surgical Management of Breast Cancer

The article selection process was conducted using a PRISMA-guided flow. The initial search identified 16,908 articles, consisting of 8 articles from PubMed, 0 articles from Garuda, and

16,900 articles from Google Scholar. During the first screening stage, 840 articles were excluded because they were not written in Indonesian or English, leaving 16,068 articles for further screening. The remaining articles were then assessed based on full-text availability and completeness of article information. At this stage, 15,732 articles were excluded because the full text was unavailable or the article information was incomplete. After this process, 336 full-text articles were assessed for eligibility.

The inclusion criteria in this review were articles published within the last 5 to 10 years, articles written in Indonesian or English, articles published in indexed or peer-reviewed scientific journals, articles discussing breast cancer imaging modalities such as mammography, ultrasonography, MRI, DCE-MRI, radiomics, or artificial intelligence-based imaging, and articles that were relevant to diagnosis, staging, tumor characterization, surgical planning, surgical decision-making, treatment response evaluation, or post-surgical management. The exclusion criteria included articles that were not relevant to breast cancer imaging, articles without full-text access, articles with incomplete article information, articles not published in peer-reviewed journals, non-Indonesian and non-English articles, and articles that did not discuss clinical decision-making or surgical management in breast cancer.

After applying the eligibility criteria, 325 articles were excluded because they were not original research articles, were not sufficiently relevant to the study focus, or were not published in peer-reviewed scientific journals. Finally, 11 articles were included in the review because they were considered the most relevant to the objective of this study. The selected articles were analyzed by extracting key information, including author names, year of publication, article title, study design, imaging modality, main findings, and relevance to surgical management. The extracted data were then synthesized narratively to explain how imaging modalities contribute to breast cancer diagnosis, staging, assessment of tumor extent, prediction of treatment response, and determination of the type and extent of surgical management.

Result and Discussion

Table 1. Analysis of the Role of Imaging Modalities in Determining Surgical Management for Breast Cancer

No	Authors	Title	Method	Results	Conclusion
1	Jiao Wu, Yongxin Li, Wanqing Gong, Qian Li, Xue Han, Tingting Zhang (2025)	Multi-modality radiomics diagnosis of breast cancer based on MRI, ultrasound, and mammography	Retrospective study; multimodal radiomics analysis using MRI, ultrasound, mammography, and machine learning	The multimodal model showed higher accuracy, sensitivity, and specificity compared with single-modality imaging	Combining imaging modalities improves breast cancer diagnostic accuracy and supports surgical planning
2	Mengyun Wang, Sijie Mo, Guoqiu Li, Jing Zheng, Huaiyu Wu, Hongtian Tian, Jing Chen, Shuzhen Tang, Zhijie Chen, Jinfeng Xu, Zhibin Huang, Fajin Dong (2025)	Deep learning and radiomics integration of photoacoustic/ultrasound imaging for non-invasive prediction of luminal and non-luminal breast cancer subtypes	Experimental study; integration of deep learning and radiomics using photoacoustic and ultrasound images	The model successfully predicted luminal and non-luminal breast cancer subtypes non-invasively with high performance	AI and imaging integration can assist subtype determination before surgery
3	Xinyu Song, Haoyi Xu, Xiaoli Wang, Wen Liu,	Use of ultrasound imaging omics in predicting molecular	Retrospective study; ultrasound-	The model predicted molecular types	Ultrasound imaging omics is useful for

	Xiaoling Leng, Yue Hu, Zhimin Luo, Yanyan Chen, Chao Dong, Binlin Ma (2024)	typing and assessing the risk of postoperative recurrence in breast cancer	based imaging omics analysis	and postoperative recurrence risk	risk stratification and post-surgical therapy planning
4	Kristin Mayer-Zugai, Iris Georgiadou, Christel Weiss, Alexander Ast, Hans Scheffel (2025)	The Impact of Preoperative Breast Magnetic Resonance Imaging on Surgical Planning: A Retrospective Single-Center Study	Retrospective single-center study; evaluation of surgical plan changes after preoperative MRI	MRI altered surgical plans in some patients, especially by detecting multifocal lesions	Preoperative MRI plays an important role in determining surgical extent and surgical type
5	Yuanyuan Liu, Xuerui Liao, Yakun He, Fawei He, Jing Ren, Peng Zhou, Xin Zhang (2025)	Tumor size and stage assessment accuracy of MRI and ultrasound versus pathological measurements in early breast cancer patients	Comparative study; comparison of MRI, ultrasound, and pathological measurements	MRI was more accurate than ultrasound in measuring tumor size and determining staging	MRI is recommended for early breast cancer surgical planning
6	Yifan Liu, Ji Gu (2025)	Utilization of breast magnetic resonance imaging in the pre-operative setting and its ability to better predict local staging in non-metastatic breast cancer patients	Retrospective study; evaluation of preoperative MRI for local staging	MRI improved staging accuracy and influenced surgical decisions	Preoperative MRI helps determine more appropriate surgical strategies
7	Michael L. Marinovich, Nehmat Houssami, Andrew Spillane, Gregory B. Mann, Donna Taylor, Michelle Reintals, Nadine Phillips, Max K. Bulsara, Patsy Siok Hwa Soon, Tracey Dickens, Christobel M. Saunders (2025)	Changes in patient management after preoperative MRI for newly diagnosed breast cancer: a multicentre prospective observational study	Prospective multicenter observational study	MRI changed clinical management and surgical plans in approximately 30% of patients	Preoperative MRI has a significant impact on surgical decision-making
8	Hari Soekersi, Yohana Azhar, Kiran Shadentyra Akbari (2022)	Role Of Mammography In Breast Cancer Screening: A Literature Review	Literature review	Mammography was found to be effective as the primary screening method for breast cancer	Mammography plays a crucial role in early detection and may influence treatment success
9	Xun Li, Peng Fu, Ming Jiang, et al. (2021)	The diagnostic performance of dynamic contrast-enhanced MRI and its correlation with subtypes of breast cancer	Retrospective study	77.63% of cases were malignant and 22.37% were benign; Ktrans and Kep were higher in malignant lesions; AUC values increased significantly; Ve was better	DCE-MRI perfusion parameters effectively differentiate benign and malignant lesions and may serve as imaging biomarkers

				for distinguishing triple-negative subtype	
10	Zixian Dong, Meilin Chen, Ying Zhou, et al. (2025)	Dynamic MRI Assessment of Early Response to Neoadjuvant Chemotherapy in Breast Cancer: A Multicenter Real-World Study	Retrospective study	Early complete radiological response was associated with improved disease-free survival; HR-/HER2+ patients with early complete response had better prognosis	DCE-MRI predicts therapy response and prognosis and may support surgical de-escalation strategies
11	Serina Azahra, Pramesti Kusumaningtyas, Mohammad Rofi'i (2025)	Early Detection of Breast Cancer Using Ultrasound Imaging Based on Convolutional Neural Networks and Particle Swarm Optimization	Experimental study; CNN and Particle Swarm Optimization implementation	The AI model showed high accuracy in breast cancer detection	Ultrasound-based AI has potential to improve early detection and support clinical decision-making

Based on the reviewed literature, 11 studies examined the role of various imaging modalities, including mammography, ultrasound, magnetic resonance imaging (MRI), and artificial intelligence-based technology, in the diagnosis, staging, surgical planning, and therapy evaluation of breast cancer.

Magnetic resonance imaging (MRI), particularly dynamic contrast-enhanced MRI (DCE-MRI), is an imaging modality with high sensitivity (>90%) in detecting breast cancer. MRI has important benefits in management, including determining the extent of lesions, detecting multifocal or bilateral lesions, evaluating therapy response, and assisting in more precise surgical planning. Furthermore, MRI also plays a role in cases with questionable mammography or ultrasound results.¹⁸

DCE-MRI works by assessing the vascularization pattern and enhancement of lesions after contrast administration. Malignant lesions generally show rapid contrast enhancement and washout, while benign lesions tend to show slow and persistent enhancement. Therefore, DCE-MRI can help differentiate benign from malignant tumors based on the morphological and kinetic characteristics of the lesion.¹⁸

In interpreting breast imaging, the standard BI-RADS (Breast Imaging Reporting and Data System) system is used to assess the level of suspicion for malignancy:¹⁸

BI-RADS 1–2: normal/benign

BI-RADS 3: likely benign

BI-RADS 4: suspicious (4A–4C)

BI-RADS 5: highly suspicious for malignancy

BI-RADS 6: proven malignancy

This system is crucial because it helps clinicians determine the next steps, such as observation, follow-up, biopsy, or surgery.¹⁸

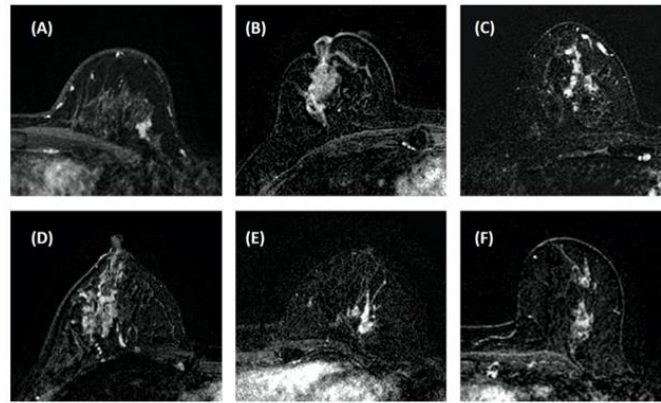


Figure 2. Case examples of internal morphology and enhancement pattern distribution evaluated based on the BI-RADS 5th edition lexicon. (A) A 47-year-old female patient diagnosed with adenosis demonstrates a focal distribution with homogeneous enhancement. (B) A 41-year-old female patient diagnosed with ductal carcinoma in situ (DCIS) demonstrates a segmental distribution with heterogeneous enhancement. (C) A 43-year-old female patient diagnosed with invasive ductal carcinoma (IDC) demonstrates a segmental distribution with clustered ring enhancement. (D) A 36-year-old female patient diagnosed with inflammation demonstrates a regional distribution with heterogeneous enhancement. (E) A 51-year-old female patient diagnosed with IDC demonstrates a regional distribution with clumped enhancement. (F) A 52-year-old female patient diagnosed with DCIS demonstrates a multiple distribution with clumped enhancement.

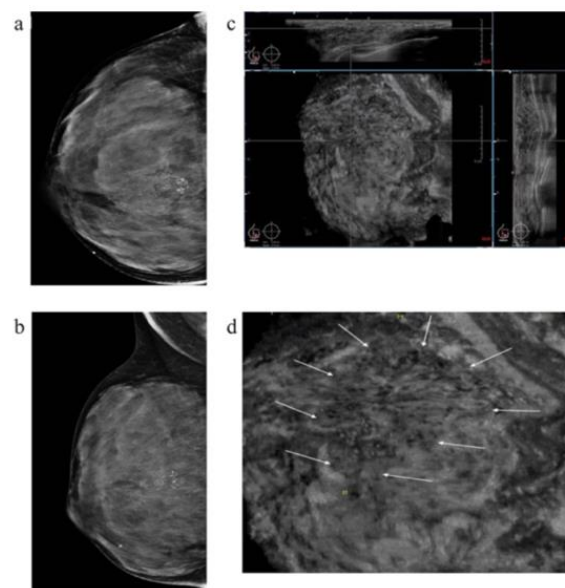


Figure 3. Imaging of a young woman with microcalcifications in the right breast pathologically confirmed as ductal carcinoma in situ with a component of invasive breast carcinoma. (a, b) Craniocaudal (CC) and mediolateral oblique (MLO) mammographic views show numerous fine, polymorphic, branching microcalcifications with a segmental distribution in the upper quadrant and central area of the right breast. Breast density is category d and is graded as BI-RADS category 4C. (c) Right breast ultrasound (ABUS) in the medial plane shows multiple dilated ducts with intraductal microcalcifications on coronal (lower left), transverse (upper), and sagittal (right) images. The lesion is graded as BI-RADS category 4C. The nipple is marked with a yellow dot, while the cross indicates the location of the lesion. (d) Shows the segmental distribution of the lesion in the medial coronal plane of the right breast (indicated by arrows).20

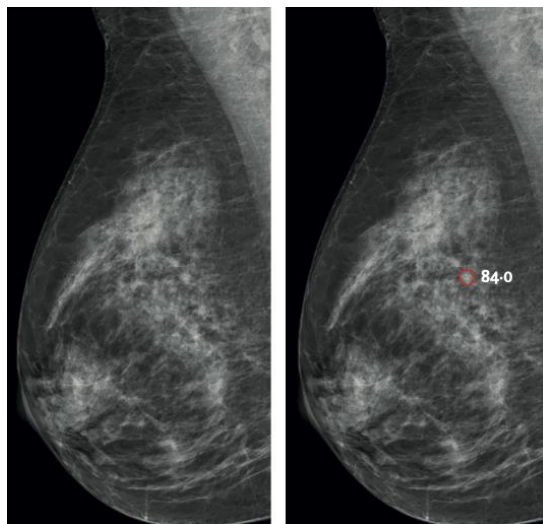


Figure 4. A mammogram revealed a small, spicule-shaped mass marked with a red circle. The patient was then recalled for further testing and diagnosed with 5 mm invasive cancer without lymph node involvement.¹⁹



Figure 5. Invasive ductal carcinoma in a 47-year-old woman with a history of left breast cancer and right breast reduction surgery. Ultrasound examination revealed an irregular hypoechoic mass correlating with the spiculated mass.¹⁸

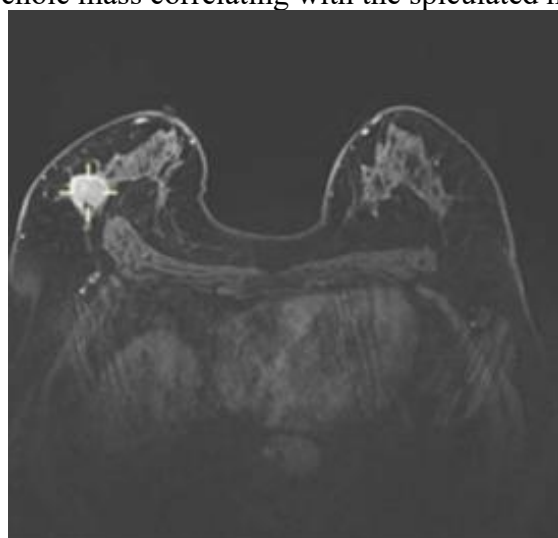


Figure 6. MRI image of a 54-year-old woman with nonspecific invasive breast cancer, showing breast tumor size measurements using MRI with multiplanar reconstruction (MPR).¹²

Research by Jiao Wu et al. (2025) demonstrated that the use of multimodal radiomics, combining MRI, ultrasound, and mammography, provided higher accuracy, sensitivity, and specificity than using a single imaging modality alone. This finding confirms that a multimodal approach can provide a more comprehensive picture of tumor characteristics, potentially improving surgical planning accuracy.⁷ Similar results were also supported by research by Mengyun Wang et al. (2025), which integrated deep learning and radiomics into photoacoustic and ultrasound images. The developed model was able to predict breast cancer subtypes non-invasively with high performance. This subtype information is highly relevant in determining therapeutic strategies, including surgical approaches and adjuvant therapy.⁸

Furthermore, research by Xinyu Song et al. (2024) highlighted the role of omics ultrasound imaging in predicting molecular type and risk of postoperative recurrence. This study demonstrated that imaging not only plays a role in the preoperative phase but also has predictive value for postoperative outcomes. This suggests that imaging can be used as an aid in risk stratification and planning further therapy after surgery.⁹

The role of preoperative MRI has been specifically discussed in several studies. Kristin Mayer-Zugai et al. (2025) reported that preoperative MRI can alter surgical planning in some patients, primarily through the detection of multifocal lesions not identified by conventional modalities.¹⁰ This finding aligns with research by Yifan Liu and Ji Gu (2025), which demonstrated that MRI improves the accuracy of local staging and directly influences surgical strategy selection in patients with non-metastatic breast cancer.¹¹ Furthermore, a comparative study by Yuanyuan Liu et al. (2025) confirmed that MRI has a higher level of accuracy than ultrasonography in assessing tumor size and disease stage, making it more recommended for surgical planning in early-stage breast cancer.¹²

The impact of preoperative MRI on clinical management was also demonstrated in a prospective, multicenter study by Marinovich et al. (2025), which reported that MRI altered surgical management plans and treatment in approximately 30% of patients with newly diagnosed breast cancer. This confirms that MRI not only improves diagnostic accuracy, but also significantly contributes to more appropriate clinical decision-making.¹³

From an early detection perspective, Hari Soekersi et al. (2022) confirmed through a literature review that mammography remains the primary modality for breast cancer screening. Early detection through mammography plays a crucial role in detecting cancer at an early stage, which directly increases the chances of conservative surgery and improves patient prognosis.¹⁴ Developments in artificial intelligence technology also support early detection, as demonstrated by research by Serina Azahra et al. (2025), who found that the application of convolutional neural networks and particle swarm optimization to ultrasound images resulted in high accuracy in detecting breast cancer.¹⁵

In addition to diagnostic and preoperative imaging, several studies have addressed the role of imaging in advanced therapy. Xun Li et al. (2021) reported that in an analysis of 76 breast cancer patients, DCE-MRI perfusion parameters demonstrated good ability to differentiate benign from malignant lesions, with significantly higher K_{trans} and K_{ep} values in malignant lesions ($p < 0.001$). Furthermore, the AUC value indicates high diagnostic performance (K_{trans} 0.858; K_{ep} 0.926; V_e 0.827), suggesting that these parameters have the potential to be used as biomarkers in determining the characteristics of breast cancer subtypes, particularly triple-negative.¹⁶

Research conducted by Zixian Dong et al. (2025) stated that evaluating radiological complete response (CR) using DCE-MRI in breast cancer patients undergoing neoadjuvant chemotherapy showed a significant association with improved disease-free survival (DFS). Patients with early CR, particularly those with HR-/HER2+ subtypes, had a better prognosis

compared to those with later CR ($p < 0.05$), thus DCE-MRI can be used to predict therapy response and assist in determining de-escalation strategies for surgical treatment.¹⁷

Overall, the results of this study demonstrate that imaging modalities play a crucial role across the entire spectrum of breast cancer management, from early detection and diagnosis, staging, surgical planning and decision-making, to post-operative therapy evaluation. The integration of various imaging modalities and the use of artificial intelligence-based technology have the potential to improve the accuracy and individualization of surgical treatment. Therefore, optimizing the use of imaging modalities needs to be an integral part of a multidisciplinary approach to breast cancer management to improve patient clinical outcomes.

Conclusion

Based on the eleven reviewed studies, imaging modalities play an essential role in breast cancer management, particularly in supporting diagnosis, staging, clinical decision-making, and the determination of the type and extent of surgical treatment. Mammography, ultrasonography, magnetic resonance imaging (MRI), dynamic contrast-enhanced MRI (DCE-MRI), and artificial intelligence-based imaging technologies provide important information regarding tumor size, lesion characteristics, disease extent, surrounding tissue involvement, multifocality, bilaterality, and treatment response. These findings help clinicians determine whether patients are more suitable for breast-conserving surgery, mastectomy, surgical de-escalation, or further therapeutic planning.

The review also shows that imaging modalities are not merely diagnostic tools, but strategic components in individualized surgical planning for breast cancer patients. MRI and DCE-MRI are particularly valuable in assessing local staging, detecting multifocal or bilateral lesions, and evaluating response to neoadjuvant therapy, while mammography and ultrasonography remain important for early detection and lesion characterization. The integration of artificial intelligence-based imaging further strengthens the potential for more accurate and personalized clinical decision-making. Therefore, the use of imaging modalities should be optimized through a multidisciplinary approach involving surgeons, radiologists, oncologists, and other related healthcare professionals. Further research is recommended to evaluate the long-term impact of integrated imaging strategies on surgical outcomes, reoperation rates, prognosis, and quality of life among breast cancer patients.

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