

Review Article

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Comparative Evaluation of Digital Breast Tomosynthesis and Contrast-Enhanced Mammography in Breast Cancer Screening

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ABSTRACT

Background: Breast cancer remains a leading cause of cancer-related mortality and is the most frequent cancer diagnosed in women globally. Early detection by imaging screening is crucial to reducing disease-specific mortality and improve treatment outcomes. The traditional screening modality for many years has been conventional digital mammography (DM); however, its diagnostic accuracy is known to be influenced by lesion morphology, breast density, and technical limitations, which can increase recall rates and reduce sensitivity. To overcome the limitations of conventional imaging modalities, advanced imaging modalities, such as digital breast tomosynthesis (DBT), contrast-enhanced mammography (CEM), and magnetic resonance imaging (MRI), have been developed. Although these advanced imaging modalities have been developed, it is still challenging to select the optimal imaging modality because of the differences in their accuracy, cost, accessibility, radiation exposure, and rates of false positives. As such, a comprehensive review of the current breast imaging modalities is needed.

Methods: A systematic literature search was performed on PubMed, Scopus, Google Scholar, and Web of Science to identify literature published between 2010 and 2025. The keywords used included breast cancer screening, digital mammography, DBT, contrast-enhanced mammography, breast MRI, and BI-RADS. Studies evaluating clinical outcomes, sensitivity, specificity, and diagnostic accuracy were included.

Result: Digital breast tomosynthesis is found to have improved lesion conspicuity and reduced recall rates when compared to digital mammography. Contrast-enhanced mammography and MRI are more sensitive in high-risk women and those with dense breasts. Various modalities have varying costs, radiation exposure, availability, and false-positive rates.

Conclusion: Breast imaging has moved towards a risk-adapted and multimodal approach. Although digital mammography is still the cornerstone, a combination of structural and functional imaging modalities is the best approach for optimal detection, especially in dense breasts and high-risk patients. Tailored imaging strategies, facilitated by the use of BI-RADS and artificial intelligence, are the key to achieving optimal diagnostic outcomes with a minimum of unnecessary procedures.

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Introduction

Breast cancer is the most common type of cancer diagnosed in women worldwide and one of the main causes of cancer deaths. In 2022, there were 2.3 million new cases and 685,000 deaths due to breast cancer reported worldwide, which accounted for 23.8% of all cancer cases and 15.4% of all cancer deaths in women; in addition, an update in 2024 on the IARC site indicates that there is evidence that female breast cancer has surpassed lung cancer as the most diagnosed cancer worldwide [1]. Breast Cancer is a kind of tumour that usually takes place in the inner lining of the epithelial tissues, milk ducts, and/or lobules. The cause of this tumour is associated with various reasons, including the inheritance of mutations in the genes, exposure to radiation in the past, and hormonal imbalance. It has now become the leading cause of cancer-related illnesses and deaths among females [2].

As mammographic density affects the detection of cancer, the risk of breast cancer attributed to mammographic density could be biased. The risk could be underestimated if it is calculated only on cancers detected at screening, since cancers obscured by dense breast tissue would be excluded. The risk could also be overestimated if it is calculated only on cancers detected by methods other than screening, since cancers not detected by screening would be overrepresented [3].

The key to the diagnosis of breast cancer is triple diagnostics: clinical examination, imaging, and biopsy. The clinical examination involves breast and axillary palpation. Different imaging techniques can be employed in the event of suspected breast cancer. These include mammography, Contrast-Enhanced Mammography (CEM), breast tomosynthesis, ultrasound, and Magnetic Resonance Imaging (MRI) [4].

Full-field digital mammography, which offers better contrast resolution, image manipulation capabilities, digital storage, and increased workflow efficiency, has supplanted traditional film-

screen mammography because of technological advancements. Notwithstanding these developments, a major diagnostic obstacle still exists due to the intrinsic limitations of two-dimensional imaging, specifically tissue superimposition [5].

Breast density is another important factor that affects the performance of the diagnostic system. Dense fibroglandular tissue not only decreases the sensitivity of the mammographic image by hiding the lesions, but it is also identified as an independent risk factor for the development of breast cancer. Research has revealed that women with extremely dense breasts have lower detection rates and higher rates of interval cancer incidence than women with fatty breasts [6].

Methodology

Study Design

The systematic review was carried out following the guidelines provided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020).

Data Sources and Search Strategy

The literature search was carried out in the PubMed, Scopus, and Web of Science databases to identify relevant studies that were published between January 2010 and March 2025. The search strategy was carried out using a combination of Medical Subject Headings (MeSH) and free-text terms. The search terms included: “breast cancer screening,” “digital mammography,” “digital breast tomosynthesis,” “contrast-enhanced mammography,” “breast MRI,” “BI-RADS,” and “artificial intelligence in breast imaging.”

Eligibility Criteria

Inclusion Criteria

Original research articles assessing diagnostic accuracy
Articles reporting sensitivity, specificity, cancer detection rate, or recall rate
Comparative studies of two or more imaging modalities
Studies among adult female populations
Articles published in English

Exclusion Criteria

Case reports, editorials, letters, and abstracts
Animal studies or studies involving only phantom data
Insufficient methodological information
Duplicate publications

Study Selection

The retrieved records were independently screened based on the title and abstract. The full-text articles were then screened for eligibility based on the predefined criteria. The duplicate records were removed before screening. Any discrepancies in the study selection process were resolved by discussion.

Data Extraction

Data was extracted using a standardized form that included the following:
Author and year of publication
Study design
Population characteristics
Imaging modality evaluated
Diagnostic performance outcomes

Data Synthesis

Because of heterogeneity among the studies in design, imaging parameters, and outcome measures, a quantitative meta-analysis

could not be performed. Hence, data synthesis was done qualitatively, comparing the diagnostic performance of each imaging modality.

Digital Mammography (DM)

Breast cancer risk prediction is a crucial step in helping high-risk female individuals benefit from earlier or more frequent screening, supplemental screening techniques, or preventive strategies. Digital mammography (DM) is the most widely used breast cancer screening technique globally and has been the gold standard for many years [7]. Breast density, measured from DM, is an independent risk factor for breast cancer and has been included in risk models [8].

Mammography: A mammogram is a 2D image that assists in the identification of morphologically suspicious lesions in breast cancer. These lesions include masses, asymmetric calcifications, and distorted areas of the breast. In this technique, the breast is compressed with a plate, and 2D radiographic images are created by passing low-energy (20-32 kVp) X-rays through the breast tissues. A routine mammographic image is taken in the oblique views (MLO) and craniocaudal (CC) of each breast (Fig.1) [9]. However, its sensitivity is greatly affected by breast density. Dense fibroglandular tissue can hide lesions, leading to a lower rate of detection and a higher rate of interval cancers [10]. The intrinsic drawback of two-dimensional imaging is also responsible for false-positive recalls due to tissue overlap [11].

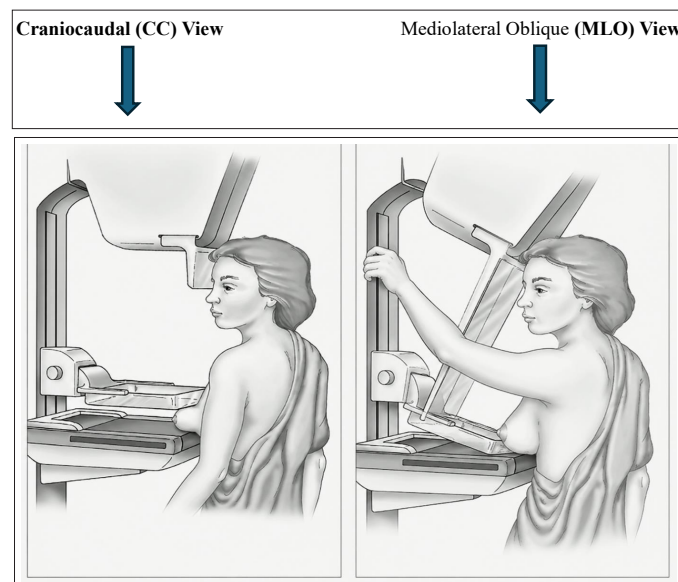


Figure 1: Mammography Positioning

Digital Breast Tomosynthesis (DBT)

Digital breast tomosynthesis (DBT) was introduced to address the limitation of tissue superimposition in two-dimensional mammography. DBT allows the creation of quasi-three-dimensional images of the breast by acquiring a series of low-dose projection images from various angles [12]. Several large-scale screening trials have shown that the combination of DBT and digital mammography is associated with an increased rate of cancer detection and a reduced rate of recall compared with mammography alone [13]. The improved visualisation of architectural distortion and spiculated lesions improves diagnostic accuracy, especially in women with dense breasts [14]. The dose of radiation used in DBT is within the acceptable limits of safety and is equivalent to conventional digital mammography when two-dimensional images are employed [15].

Although DBT has several advantages, it is a major step forward in the screening process, as it enhances the visibility of lesions and decreases the rate of false-positive recalls, especially in women with dense breasts [16].

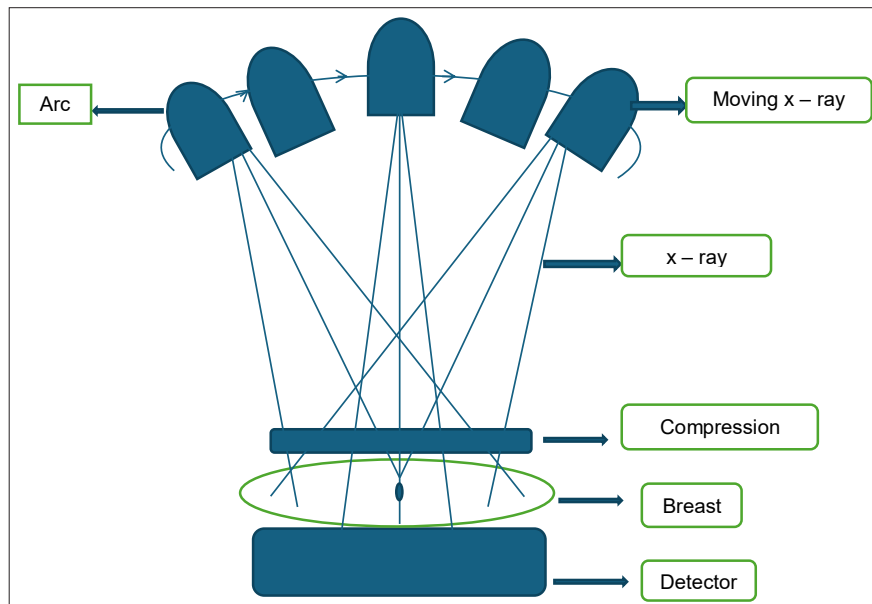


Figure 2: Digital Breast Tomosynthesis

Contrast-Enhanced Mammography (CEM)

Contrast-Enhanced Mammography (CEM) is a hybrid imaging modality that combines digital mammography with intravenous iodinated contrast agents to enable both morphological and functional analysis of breast lesions. This imaging modality relies on dual-energy imaging to delineate regions of high vascularity, which are indicative of tumour-induced neo angiogenesis [17]. Clinical trials have shown that CEM is highly effective in enhancing sensitivity over conventional mammography, especially in women with dense breast tissue and in situations where mammography is inconclusive [18]. There are several studies that have shown diagnostic performance to be close to that of breast MRI for index cancer detection [19].

CEM has some advantages over MRI, including shorter examination time, greater accessibility, and better patient tolerance. However, CEM requires radiation exposure and the use of contrast, which has a small risk of allergic reactions [20,21].

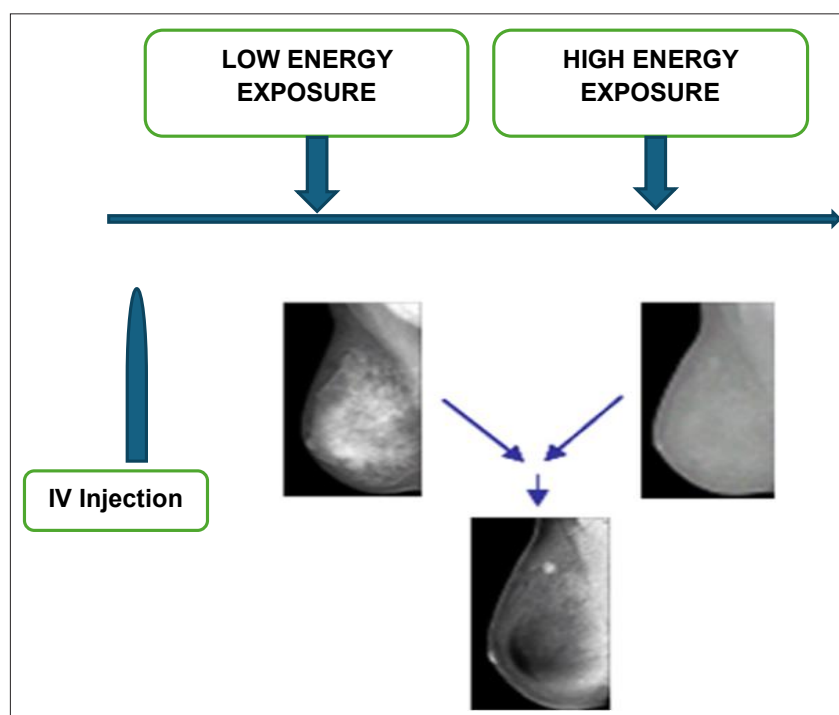


Figure 3: Dual Energy Subtraction

Breast Magnetic Resonance Imaging (MRI)

Breast MRI (magnetic resonance imaging) is a test that uses radio waves and a strong magnetic field to create pictures of the inside of the breast. A screening breast MRI is recommended in addition to a yearly mammogram. While an MRI can detect some cancers that would not be visible on a mammogram, it is also more likely to detect abnormalities that are not cancer (a false positive). This is why an MRI is not recommended for women at average risk of breast cancer as a screening tool [22].

If you are having a breast MRI, it is important to have it done at a centre that has the necessary equipment to perform an MRI-guided breast biopsy if needed. Numerous prospective studies have confirmed that MRI substantially increases cancer detection rates in high-risk groups, including BRCA carriers and women with a strong family history of breast cancer [23]. MRI is also more accurate in evaluating tumour extent, multifocality, multicentricity, and contralateral disease than mammography and ultrasound [24]. Dynamic contrast-enhanced MRI (DCE-MRI) enables kinetic curve analysis (Type I, II, III), which enhances lesion characterisation and differentiation between benign and malignant lesions [25].

Table 1: Comparison between Digital Breast Tomosynthesis and Contrast-Enhanced Mammography

S NO.	Parameter	DBT (digital breast tomosynthesis)	CEM (contrast-enhanced mammography)
1.	Image technique	Multiple low dose x-ray images reconstructed into thin slices (3D).	Dual-energy X-ray after iodine contrast injection
2.	Primary information	Shows structural details clearly and reduces tissue overlap.	Shows functional/vascular activity through contrast enhancement.
3.	Diagnostic strength	Strong for detecting masses and architectural distortion, especially in dense breasts.	Very strong for highlighting malignant lesions because tumors enhance.
4.	Radiation dose	Slightly higher than standard mammography.	Higher than DBT due to dual exposures.
5.	Contrast usage	No contrast needed.	Requires iodine-based contrast injection.
6.	Best clinical use	Screening and general diagnostic evaluation.	Diagnostic problem-solving and MRI alternative.
7.	Micro calcifications	Generally visible but sometimes limited.	Only visible clearly when they are enhanced with contrast.
8.	Patient suitability	Suitable for almost all patients.	Avoid in contrast to allergy or kidney impairment.
9.	Procedure time	Quick, like routine mammography.	Slightly longer due to contrast injection, but still faster than MRI [26].

Breast Imaging Reporting and Data System (BI-RADS)

The Breast Imaging Reporting and Data System (BI-RADS) is a system of reporting and assessment for breast imaging that has been developed by the American College of Radiology (ACR) [27].

Table 2: BI-RADS Assessment Categories and Clinical Implications

Category	Definition	Means
0	Incomplete Additional imaging evaluation	This indicates that the radiologist may have detected a potential abnormality, but it was unclear, and you will require additional testing, such as an additional mammography using spot compression (applying compression to a smaller area during the mammogram), magnified views, special mammogram views, and/or ultrasound.
1	Negative	It's a typical test result. There are no lumps, deformed structures, or suspicious calcifications on your symmetrical breasts. Negative indicates that nothing novel or unusual was discovered in this instance.
2	Benign(noncancerous) finding	The radiologist decides to describe a finding that is not cancer, such as benign calcifications, masses, or breast lymph nodes, even though the test result is likewise negative (there is no sign of cancer). This can also be used to describe changes in the breast following a previous procedure (like a biopsy) [28].
3	Probably benign finding– Follow-up in a short time frame is suggested	There is a very small (less than 2%) chance that a finding in this category is cancer. Over time, it is not anticipated to change. Repeat imaging will probably be required for follow-up in 6 to 12 months, and then regularly until the finding is known to be stable (usually at least 2 years).
4	Suspicious abnormality: Biopsy should be considered	These results could be cancer, even though they don't appear to be. The radiologist is so worried that a biopsy is suggested. This category is divided as follows- 4A: Identification with a low probability of cancer (above 2% but below 10%) 4B: Determining that there is a moderate chance of cancer (more than 10% but not more than 50%) 4C: A finding that is more than 50% but less than 95% likely to be cancer, but not as high as Category 5.
5	Highly suggestive of malignancy. Appropriate action should be taken	The results have a high probability of being cancer (at least 95%) and appear to be cancer. A biopsy is highly advised.
6	Known biopsy-proven malignancy. Appropriate action should be taken	Only results from a mammogram (or ultrasound or MRI) that have previously been determined to be cancerous by a biopsy fall into this category. In this way, imaging can be used to assess how well the cancer is responding to treatment [29].

BI-RADS assign a rating from 0 to 6 to the findings, and the rating correlates the radiologic assessment with a specific action [30].

Artificial Intelligence (AI) in Breast Imaging

Artificial intelligence (AI), especially deep learning algorithms, has recently been recognized as a revolutionary technology in breast imaging. AI algorithms are designed to process a large amount of imaging data [31].

In digital mammography and digital breast tomosynthesis, computer-aided detection systems based on AI algorithms have shown better cancer detection rates and a decrease in the number of false-negative results [32]. In DBT, AI also helps in handling large data volume by allowing the prioritization of suspicious slices, thus increasing the efficiency of reading [33].

In contrast-enhanced mammography and breast MRI, the use of AI is based on the analysis of enhancement patterns, lesion segmentation, and kinetic curve analysis. Machine learning has been shown to have potential in improving specificity and predicting response to therapy, especially in dynamic contrast-enhanced MRI datasets [34,35].

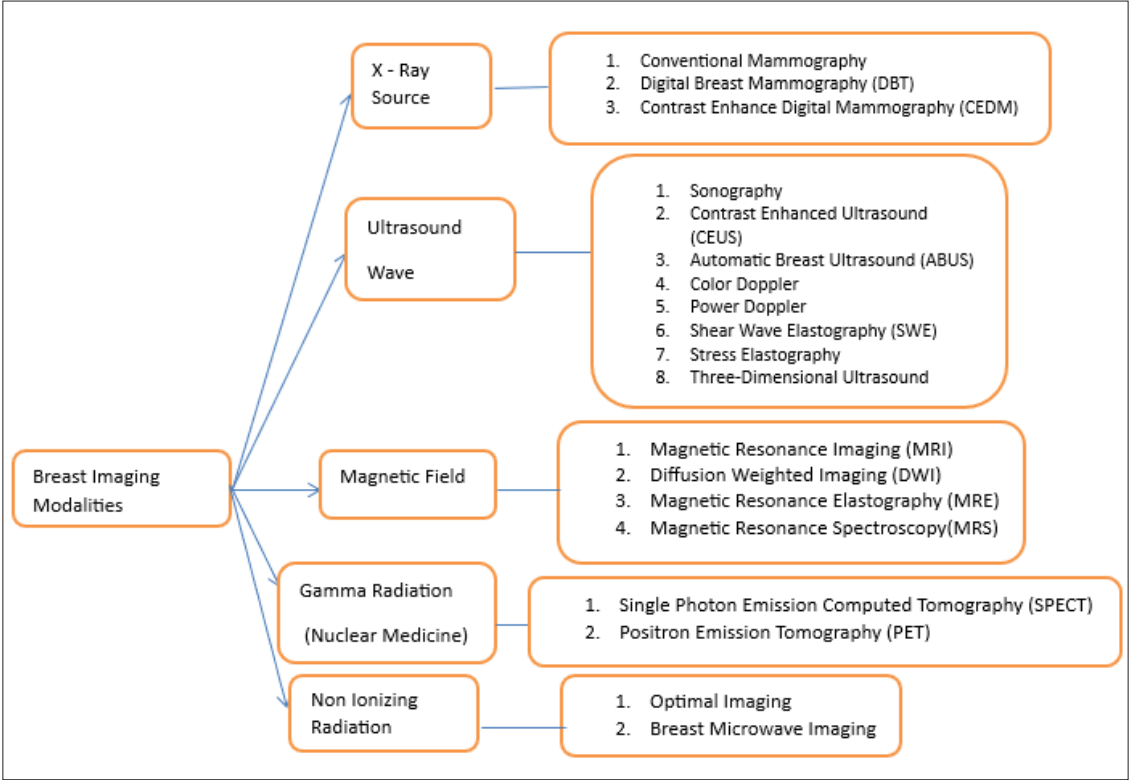


Figure 3: Comparative Analysis of Breast Imaging Modalities

The comparative analysis of breast imaging modalities has shown that each of them has its own advantages and disadvantages in the diagnostic process. Digital mammography is still the main screening tool because of its availability, standardisation, and proven reduction in mortality [36]. Nevertheless, its sensitivity drops dramatically in women with dense breasts.

Digital breast tomosynthesis enhances the visibility of lesions by minimising tissue overlap and has been proven to have a higher rate of cancer detection and a lower rate of recall compared with conventional digital mammography [37].

Contrast-enhanced mammography offers functional imaging based on the neoangiogenic process of tumours and has shown equal diagnostic accuracy to breast MRI in several studies, with greater accessibility and shorter procedure time [38].

Breast MRI is currently the most sensitive technique for cancer detection, especially in high-risk women and in preoperative staging. Nevertheless, its reduced specificity, increased cost, and limited availability preclude its widespread use [39].

Table 4: Advantages and Limitations of various Imaging Techniques Used in Breast Imaging

Imaging Technique	Advantages	Limitations
Mammography	Widely available, relatively inexpensive, and effective for detecting microcalcifications. It has been shown to reduce breast cancer mortality through early detection.	Sensitivity decreases in women with dense breast tissue. May lead to false-positive findings, involves ionising radiation, and requires breast compression, which can be uncomfortable.
Ultrasound	Useful for distinguishing solid masses from cysts, it works well in dense breast tissue and has no radiation exposure.	Highly operator-dependent, less sensitive for very small tumours, may miss micro calcifications, and is not reliable as a standalone screening test.
Magnetic Resonance Imaging (MRI)	Highly sensitive, provides excellent soft-tissue contrast, is useful for high-risk patients, and does not use ionizing radiation.	Expensive, time-consuming, less widely available, has a higher false-positive rate, and often requires the use of contrast agents [40].

Results

Findings show that digital mammography is still the main screening tool but has decreased sensitivity in dense breasts. Digital breast tomosynthesis increases the ability to detect cancer and decreases the rate of recall by decreasing tissue overlap, especially in invasive cancers. Contrast-enhanced mammography increases sensitivity by functional vascular analysis and has equal diagnostic capabilities to MRI in specific clinical situations, especially in lesion characterization and assessment. Breast MRI is the most sensitive technique, especially in high-risk patients and in preoperative assessment; however, increased cost, availability, and false-positive rates limit its use in average-risk screening. Artificial intelligence algorithms further improve detection capabilities and help in risk assessment and workflow efficiency in all imaging modalities.

Discussion

This review illustrates that the field of breast imaging has progressed from a single-modality concept to a risk-adapted, multimodal approach. While digital mammography continues to form the cornerstone of screening protocols, its decreased sensitivity in dense breasts requires additional modalities. Digital breast tomosynthesis enhances anatomical imaging and lowers recall rates, while contrast-enhanced mammography and MRI enable functional imaging based on tumour vascularity.

Breast MRI remains the most sensitive, especially in high-risk women and for staging, although the expense and false positives are still concerns. Notably, there is no imaging modality that provides the optimal combination of sensitivity, specificity, accessibility, and feasibility. This practice trend argues for the use of personalized imaging algorithms based on breast density and risk factors. The application of the BI-RADS standardization and the use of artificial intelligence in breast imaging is further enhanced.

Limitations

The main limitation of this review is the presence of considerable heterogeneity in study design, patient population, and imaging protocols, which made it difficult to compare the results of different modalities. Moreover, the current evidence for new modalities like contrast-enhanced mammography and artificial intelligence is largely from specialised or developed centres, which may not be easily generalizable. Long-term results regarding mortality reduction, cost-effectiveness, and overdiagnosis are still not adequately established.

Future Scope

The future of breast imaging is in the creation of risk-adapted screening models rather than the current reliance on a single

modality. Moving towards personalised imaging strategies, based on breast density, genetic risk, and clinical presentation, will be crucial in optimising early detection while avoiding unnecessary investigations.

Well-designed prospective studies and multicentre trials will be necessary to demonstrate long-term clinical benefit, including survival benefit, cost-effectiveness, and reduction in overdiagnosis. Further technological improvements, coupled with the judicious use of decision-support tools, may help improve diagnostic accuracy. The future will continue to prioritize the availability of advanced imaging technologies in all healthcare settings to improve breast cancer detection strategies worldwide.

Conclusion

Breast imaging has seen a lot of development, moving from a traditional single-modality paradigm to an integrated and risk-stratified approach. Although digital mammography continues to be the backbone of screening protocols, its shortcomings, especially in dense breasts, make it necessary to have supplemental imaging with more advanced modalities. Digital breast tomosynthesis improves anatomical detail, contrast-enhanced mammography and MRI offer complementary functional information, and new decision-support tools will further enhance diagnostic performance.

Notably, there is no single imaging modality that is best suited for all patients. There is evidence to support a risk-stratified and multimodality approach, which has the potential to enhance early detection with fewer unnecessary procedures, ultimately helping to achieve more precise breast cancer care.

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