



Review Article

Cutting-edge Imaging Breakthroughs for Early Breast Cancer Detection



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Received: December 31, 2024 | Revised: March 12, 2025 | Accepted: March 27, 2025 | Published online: March 30, 2025

Abstract

Breast cancer remains one of the leading causes of cancer-related deaths worldwide. Early detection of breast cancer significantly improves outcomes and survival rates, minimizing treatments. Imaging techniques are critical in identifying abnormalities and diagnosing breast cancer at its earliest stages, often before clinical symptoms emerge. Mammography remains standard for screening in average-risk women, while supplementary methods like ultrasound, magnetic resonance imaging, and tomosynthesis enhance detection rates, particularly in women with dense breasts or those at high risk. Given that certain factors, such as family history, age, genetic mutations, and breast density, affect the risk of developing breast cancer, some women may benefit from earlier or more frequent screenings. Personalized screening protocols are becoming more common, tailoring the type and frequency of imaging to the individual's risk profile. Newer technologies, such as molecular breast imaging and contrast-enhanced mammography show promise but require further validation for widespread use. In conclusion, imaging techniques including mammography, ultrasound, magnetic resonance imaging, and newer technologies like three-dimensional mammography and molecular breast imaging are essential tools in the early detection of breast cancer, leading to better outcomes for patients. This literature review provides an overview of current breast cancer imaging methods, their role in early diagnosis, and their effectiveness and limitations.

Introduction

Breast cancer commonly refers to a malignant neoplasm that develops in breast tissue.^{1–3} Worldwide, breast cancer is the main type of neoplasm in women and accounts for 25% of all cancer cases.⁴ In 2022, female breast cancer was the second most commonly diagnosed cancer worldwide, with approximately 2.3 million new cases and 670,000 deaths. It is more common in developed countries and is more than 100 times more common in women than in men.⁵ Prognosis varies depending on the type, extent of the disease, and age of the patient. Survival rates in the developed world are high, with estimated values ranging between 80% and 90% at five years post-diagnosis. In developing countries, these values are much lower.

Most types of breast cancer are easy to diagnose through microscopic analysis of a sample or biopsy of the affected area. How-

ever, there are rarer types of cancer that require specialized laboratory tests. Once diagnosis is made, further tests can be conducted to determine if and how much cancer has spread and which treatment to prefer.⁶ With breast cancer screening, we refer to the tests proposed to otherwise healthy women to obtain an early diagnosis, under the assumption that it will improve prognosis. Several tests have been suggested, including clinical breast examination and self-examination, mammography, genetic screening, ultrasound, and magnetic resonance imaging (MRI).^{7,8}

A clinical or self-breast examination involves palpating the organ to check for any lumps or other abnormalities. Clinical examinations are performed by healthcare personnel, while self-examination is carried out by the individuals themselves. However, scientific evidence does not fully support the effectiveness of either type of examination.⁹ Mammography is an exam that uses X-rays to examine the breast to highlight any unusual masses or nodules. During the examination, the breast is compressed, and different projections are taken at various angles and possibly with different magnifications.^{10–18}

When these tests are inconclusive, the healthcare provider can remove a sample of the nodule for microscopic analysis, a procedure known as fine-needle aspiration cytology, to arrive at a diagnosis. Physical examination of the breast, mammography, and cytological sampling, when used together, are methods that can allow

Keywords: Breast cancer; Diagnosis; Screening; Mammography; Ultrasound; Magnetic resonance imaging; Fine needle aspiration; Tomosynthesis; Thermography.

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How to cite this article: Comparetto C, Borruto F. Cutting-edge Imaging Breakthroughs for Early Breast Cancer Detection. *Cancer Screen Prev* 2025;4(1):21–39. doi: 10.14218/CSP.2024.00032.

for breast cancer diagnosis with a good degree of accuracy. Other options regarding biopsy may include ultrasound-guided core biopsy or vacuum-assisted biopsy, both of which are procedures in which a portion of the nodule is removed for analysis. Very often, the results of physical examination by a healthcare provider, mammogram, and additional tests that may be performed under specific circumstances, such as breast ultrasound and MRI, are sufficient to justify excisional biopsy as a method of definitive primary diagnostic treatment.^{19–21}

The aim of the present review is to explore recent advancements in imaging techniques for early breast cancer detection. It focuses on evaluating the effectiveness, accuracy, and clinical applications of modern imaging modalities such as digital mammography, breast ultrasound, MRI, positron emission tomography (PET), molecular breast imaging, and breast thermography. The study aims to highlight how these innovations improve early diagnosis, enhance patient outcomes, and contribute to more personalized and effective breast cancer screening strategies.

Mammography

Mammography is a special type of radiographic imaging used to create detailed images of the human breast performed using a low dose (usually around 0.7 mSv) of X-rays. It is estimated that 48 million mammograms are performed each year in the United States (US). Mammography uses low-dose X-rays obtained using low-atomic-weight alloy targets. Aluminum, molybdenum, beryllium, rhodium, and palladium filters are used. It uses high-contrast, high-resolution (with single-sided emulsion) film to demonstrate microcalcifications smaller than 100 microns.^{22–24}

There are two types of mammograms: screening and clinical. Mammographic screening is used in asymptomatic women. Early diagnosis of small breast cancers through mammographic screening significantly improves a woman's chances of successful treatment. Studies have also shown that mammographic screening should not be based solely on age and family history of breast cancer but also on breast density, previous breast biopsy history, and knowledge of the cost/benefit balance of screening.²⁵ Diagnostic mammography is performed in symptomatic women in the presence of a breast lump or bloody discharge noted during self-examination or when an anomaly is detected during mammographic screening. Diagnostic mammography takes more time than screening mammography and is used to determine the exact size, the location of the finding in the breast, and to study the surrounding lymph nodes.²⁶ Typically, various additional breast projections are performed and interpreted during diagnostic mammography. Thus, diagnostic mammography is more expensive than screening mammography. Women with breast implants or a personal history of breast cancer usually require additional examinations, such as ultrasound or MRI, used in conjunction with diagnostic mammography.^{27,28}

Until a few years ago, mammography was performed using cassettes containing radiographic films. Now, mammography is transitioning to digital detectors, known as “digital mammography”.^{29,30} Mammography plays an important role in early diagnosis of breast cancer, detecting about 75% of cancers at least a year before they can be felt. Mammography uses low-dose ionizing radiation, which can be harmful to women. However, the benefits of mammography far outweigh its risks and discomforts. Radiologically, the breast is composed of areas of different densities, and since these areas will be reproduced in a single image, there will be well-studied zones next to poorly represented areas.

One of the factors hindering cancer diagnosis in mammography is that the nodule has too low of a contrast difference compared to the surrounding tissue. The traditional mammographic image is a film image that, once taken, cannot be modified. Since the digital image can be processed after acquisition, density differences are overcome, making diagnosis easier.

The indirect digital or computed radiography (CR) method should be preferred over the analog system due to the following reasons: better contrast, absence of artifacts (dirty cassettes), reading on a monitor, and the image can be processed and transmitted. However, not all proposed CR systems allow for diagnostic accuracy superior to analog mammography.³¹ Dedicated direct digital machines undoubtedly yield better results compared to indirect digitization methodologies. It is useful to clarify that direct digital mammography acquires images in real time by converting X-rays into an electrical signal, while indirect digital mammography scans images from an analog mammography machine using photostimulable phosphors contained in a plate, which, once exposed to X-rays, releases light that can be detected by a laser. CR, therefore, uses available analog equipment associated with a laser reading system connected to phosphor cassettes that convert X-ray energy into light, and the signal is recorded in the form of latent images on film. Digitalization is achieved through photostimulable phosphor plates (indirect CR method) or through flat-panel systems that utilize substances to convert X-rays into light rays. The plates used contain elements capable of transforming the lines into electronic signals. The image is processed on a high-definition monitor. Digital mammography has greater sensitivity than traditional systems, managing to compensate for any exposure limits. Digital technology reduces radiation dose by 30% with expected reduction factors of 30–50% compared to analog.³²

The main advantage of digital technology is that it separates the image recording from the moment of viewing. In digital mammography, the mammographic image is captured and recorded electronically and then processed, analyzed, and displayed. Acquisition, processing, visualization, and storage of the image on the monitor allow for the optimization of the various processes because these moments are separate and therefore all improvable. The image displayed on a high-definition monitor and no longer on film allows for modification and improvement of contrast, brightness, and magnification and is subsequently recorded on optical discs, on film, or sent to a picture archiving and communication system. Digital technology has greatly benefited from the arrival of selenium detectors that allow for better resolution.^{33,34}

The average glandular dose recognized internationally is an indicative parameter of the radiological risk associated with the use of mammography. Unlike what happens with analog mammography using screen-film systems, direct digital mammography systems use a technique that reduces the radiation dose by 50%. The image quality is optimal with a very low average glandular dose delivered.³⁵ Digital mammography equipment with direct scan detectors without a grid also uses different X-ray beams, spectra that are more sensitive compared to analog ones. There are tubes with a tungsten anode and filters in aluminum and rhodium. Direct digital mammography systems can be either 18 × 24 or 24 × 30 in size. From a protectionist standpoint, it is preferable to use larger detectors, as they significantly reduce the radiation dose. The radiation dose could be further reduced as optimization avoids repetition of exams and sometimes mammographic enlargements. Moreover, the availability of digital images allows for the creation of computer archives and remote transmission of mammography. In summary, the advantages of direct digital imaging are as fol-

lows: reduced dose; greater system sensitivity with the possibility of obtaining good-quality images with lower doses; better contrast resolution and therefore the ability to explore mammary structures with little or no contrast difference; ability to compensate for exposure errors, ensuring good quality for all images; reduced number of radiographs need to be performed; elimination of film development and disposal of related polluting chemicals; reduced examination time, remote transmission (teleconsultation); archiving computer systems with advantages in management, education, and research; more accurate diagnosis for cancers located in peripheral and dense areas; and possibility to apply computer-assisted identification systems (CAD). Meanwhile, the disadvantages are the high cost and the need for continuous maintenance and updates.

As of 1 March 2010, 62% of US facilities had at least one digital unit. To encourage the use of mammograms as a screening measure for breast cancer, several hospitals, oncology centers, and groups of other healthcare providers have started performing mammograms in mobile vans.³⁶ In many countries, routine mammography for elderly women is encouraged as a screening method for the early diagnosis of breast cancer. In 2009, the US Preventive Services Task Force (USPSTF) recommended that women without risk factors undergo mammography screening every two years, between the ages of 50 and 74. They found that the information was insufficient to recommend or discourage screening between the ages of 40 and 49 or over 74 years old. Overall, clinical studies have found a relative reduction in breast cancer mortality of 20–30%.^{37,38} Some physicians believe that mammograms do not reduce breast cancer mortality or at least that the evidence does not support this.³⁹

During the procedure, the breast is compressed using a dedicated instrument. Breast compression is necessary to flatten the breast so that the maximum amount of tissue can be examined. Compression allows for the uniformity of breast tissue to enhance image quality, as the reduction in thickness of the tissue that X-rays must penetrate decreases the amount of scattered radiation, which is responsible for degrading the result. This also involves the reduction of the necessary radiation dose and motion artifacts. In fact, by immobilizing the breast, motion blur can be reduced. Breast compression can cause some discomfort, but it should not cause any significant pain.⁴⁰ In screening mammography, each breast is exposed separately, and two projections of the breast are performed: one from head to toe, or cranio-caudal, and one angled in lateral view, or oblique medio-lateral. In diagnostic mammography, each breast is exposed separately, and the examination may include these and other projections based on the specific problem, including those enlarged for the study and in-depth examination of details. These additional projections can include latero-medial and medio-lateral, magnification, spot, and others. Special skin markers are sometimes used to identify certain lesions, skin abnormalities, the nipple, and other areas. Deodorants, talcum powder, or lotions can appear as calcifications when viewed on X-rays, so women are advised to avoid using them on the day of the exam.⁴¹

The quality of mammograms should be evaluated, and, if not optimal, the exams should be repeated. Mammograms of the right and left sides should be analyzed back-to-back (in a mirrored manner) with comparable projections. Lighting must be uniform, and adequate observation conditions should be maintained. Mammograms are inspected carefully. The research is conducted systematically through similar areas in both sinuses.⁴² First, breast symmetry, size, overall density, and glandular distribution should be observed. Subsequently, the search for nodules, densities, calcifications, glandular distortions, and associated findings is per-

formed. For nodules, shape, margins, and density are analyzed. Malignant lesions tend to have irregular and (usually) spiculated margins. Neoplasms, especially scirrhous cancers, tend to have a higher density than normal breast tissue. Very low density is documented in benign lesions (for example, cysts, lipomas, galactocele, hemangiomas, and hamartomas).⁴³

The most common sign of breast pathology is nodular opacity, which can be round, oval, lobulated, and irregular. Opacities with well-defined margins are usually benign in nature (cysts and fibroadenomas), while those with irregular margins are malignant, except for surgical scar outcomes and sclerosing adenosis. The most common signs of carcinoma on mammography are as follows: irregular, blurred or spiculated opacity; polymorphic microcalcifications; and glandular distortion.

The most important criterion in mammographically differentiating benign from malignant is the margin of the lesion: regular, irregular, or frankly spicular. However, some infiltrating carcinomas can rarely present a mammographic appearance of benignity, showing up with an opacity with regular margins, such as mucinous carcinoma, medullary carcinoma, intracystic carcinoma, and newly emerged high-cellularity carcinomas. In these cases, ultrasound examination and fine-needle aspiration cytology become essential as they can resolve the doubt. Other signs of carcinoma are regular opacities with microcalcifications and asymmetric densities. Not all star-shaped lesions are malignant. There are benign lesions such as sclerosing adenosis, sclerosing elastotic lesion (radial scar), epithelial hyperplasia, and mammary fibrosis that can pose serious differential diagnosis problems with malignant lesions. In distortion, the normal glandular architecture is distorted without a distinct mass. In many cases, it is the most frequent sign of a radial scar where radial spicules radiate from a focal point.

Microcalcifications should be analyzed for shape and distribution within the breast and are an exclusively mammographic finding. Granular or punctate microcalcifications are indicative of both malignant and benign pathologies.⁴⁴ One of the most commonly used classifications of microcalcifications is as follows: benign—annular, rounded, or discoid microcalcifications; 90% benign—regular rounded microcalcifications; 40% malignant—grouped punctate microcalcifications; 75% malignant—granular microcalcifications like grains of salt; and mold ductal, 100% malignant—polymorphic vermicular microcalcifications.⁴⁵

Suspected carcinomas are the clusters of granular calcifications (like grains of salt). The positive predictive value (PPV) for carcinoma with microcalcifications is approximately 20–30%. Overall, the sensitivity of mammography is about 85%. The results depend on the examination technique and the type of mammary gland. In cases of fatty breast tissue, the sensitivity is very high. Conversely, in cases of dense breast tissue, ultrasound integration is essential due to the suboptimal diagnostic reliability. In mammogram reporting, it is advisable to avoid describing the less significant findings because they often cause anxiety. On the contrary, it is useful to indicate the presence of dense breast tissue in relation to the risk of error and worthy of complementary examination by ultrasound. It is also appropriate to clearly indicate the site of the injury and whether further investigations are necessary.^{46,47}

Benign calcifications are usually larger than calcifications associated with malignancy. Usually, they are coarser, often with smooth edges, and more easily visible. Benign calcifications tend to have specific shapes: egg-shell calcifications in cyst walls, in arterial walls, popcorn-like in fibroadenomas, large and with possible branching in ectatic ducts, and small calcifications with a lucent center in the skin. Calcifications associated with malignancy

Table 1. Radiological classification of breast nodules by BI-RADS

BI-RADS classification	Description
0	Need for further image evaluation
1	Negative: normal, 5 out of 10,000, routine screening is recommended
2	Benign, 5 out of 10,000, 0% risk of malignancy (cysts, fibroadenoma, etc.), routine screening is recommended
3	Probably benign, ≤2% risk of malignancy, follow-up at 6 months or cell/tissue sampling is recommended (FNAC or biopsy)
4a	Suspicious anomaly: probably malignant, 2–50% risk of malignancy, cell or tissue sampling is recommended (FNAC or biopsy)
4b	Suspicious anomaly: probably malignant, 50–90% risk of malignancy, a biopsy is recommended (FNAC or biopsy)
5	Malignant: highly suggestive of malignancy, >90% risk of malignancy, cell or tissue sampling is recommended (FNAC or biopsy)

Category 0 is a temporary category that means additional imaging is necessary before assigning a permanent BI-RADS assessment category. In most category 0 cases, the results demonstrate benignity after completion with additional images. BI-RADS, breast imaging-reporting and data system; FNAC, fine-needle aspiration cytology.

are generally small (<0.5 mm) and often require the use of a magnifying lens to see them clearly. They tend to have a pleomorphic or heterogeneous shape, a fine linear shape, or a vermicular shape with branches (casting). The distribution of calcifications must be specified as clustered, linear, segmental, regional, or diffuse.⁴⁸ Casting-type calcifications, a subtype of microcalcifications, in mammography can be indicative of a worse prognosis in breast cancer, including a reduction in disease-free survival and overall survival. The presence of mammographic casting calcifications is an independent prognostic factor that may justify more aggressive treatment.⁴⁹ In a retrospective cohort of 1,155 patients with invasive breast cancer undergoing definitive breast surgery, 11.8% of the cohort had casting calcifications on the mammogram. Stamp-like calcifications were more likely associated with the following: metastasis in axillary lymph nodes compared to absence of metastasis (odds ratio [OR]: 1.98; $p = 0.001$); estrogen and progesterone receptor negativity compared to positivity (OR: 1.49; $p = 0.035$); human epidermal growth factor receptor 2 overexpression compared to human epidermal growth factor receptor 2-negative cancer (OR: 2.39; $p < 0.001$); and tendency towards higher histological grade (G2 vs. G1; OR: 1.62; $p = 0.063$). After a median follow-up of 60 months, the group with mold-like calcifications was associated with a shorter disease-free survival compared to the group without mold-like calcifications (78.34% vs. 90.50%; adjusted hazard ratio [HR]: 1.65; $p = 0.024$) as well as a shorter overall survival compared to the group without mold-like calcifications (84.53% vs. 96.80%; adjusted HR: 1.95; $p = 0.026$).⁵⁰

The results may show signs such as a linear density that could represent a duct full of secretions or a reniform shape of intramammary lymph nodes (with a radiolucent center). The associated frames are then taken into consideration. These include skin or nipple retraction, skin thickening (which can be focal or diffuse), trabecular thickening, skin lesions, axillary lymphadenopathy, and glandular distortion. For localization of the lesion, one of the quadrants is used, either internal or external, inferior or superior. It can also be central or retroareolar. The lesion can be described by considering its position as if it were a clock face. The breast is viewed as the face of a clock with the patient facing the observer. The depth of the lesion is described as anterior, middle, or posterior third of the breast. If the results of previous exams are available, their comparison is useful for evaluating changes. All these results are considered together in the US, and a breast imaging-reporting and data system (BI-RADS) category, according to the American

College of Radiology (ACR), is assigned in the final conclusions (Table 1).^{51,52}

The ACR has established BI-RADS to guide diagnostic routines for breast cancer. The BI-RADS system is the product of a collaborative effort among members of various ACR committees, in collaboration with the National Cancer Institute, the Centers for Disease Control and Prevention, the Food and Drug Administration, the American Medical Association, the American College of Surgeons, and the American College of Pathologists.⁵³ According to the ACR, the BI-RADS system is intended to guide radiologists and referring physicians in the decision-making process for breast cancer, facilitating the diagnostic pathway and patient care.^{54,55} The BI-RADS categories are used to standardize the interpretation of mammograms among radiologists. They are useful for statistical analysis of mammography practice, and BI-RADS results are compiled on a national basis in the US to refine mammography procedures everywhere. Each BI-RADS level has an appropriate management or follow-up plan associated with it. Of all screening mammograms performed each year, about 90% show no evidence of cancer (BI-RADS category 1), and 10% show abnormalities that require further diagnostic tests, which generally include spot or magnification compression acquisitions, mammographic visits, and/or ultrasound (BI-RADS category 0). On further imaging, about 85% of all cases are normal (BI-RADS category 1) or benign (BI-RADS category 2) and do not require further evaluation. About 15% (approximately 2% of all screening mammograms) are suspicious and require a biopsy (BI-RADS category 4 or 5). Among the cases subjected to biopsy, about 80% of anomalies are benign, and 20% are cancers.⁵⁶

The ACR's BI-RADS is very widespread and is starting to be used in Italy as well. Its purpose is to classify mammograms into six categories from 0 to 5. However, BI-RADS provides a range of PPVs for carcinomas that are highly variable. The most contested category is BI-RADS 3, where the PPV for carcinoma varies from 3% to 75%, and it often concludes with a referral for follow-up checks over time or requests for invasive investigations. BI-RADS 4, with the PPV for carcinoma ranging from 2% to 95%, also includes additional categories: BI-RADS 4a (mild suspicion), BI-RADS 4b (moderate suspicion), and BI-RADS 4c (severe suspect). These further subdivisions make the reproducibility of this diagnostic classification more complicated. For a simpler classification, some radiologists use a more schematic BI-RADS in which the diagnostic conclusions are divided into five categories: R1,

Table 2. Radiological classification of breast density by BI-RADS

Normal density	
A	The breasts are almost entirely fatty.
B	There are scattered areas of fibroglandular density.
High density	
C	The breasts are heterogeneously dense, which may obscure detection of small masses.
D	The breasts are extremely dense, which lowers the sensitivity of mammography.

BI-RADS, breast imaging-reporting and data system.

negative or normal picture (no further investigations necessary); R2, benign (no further investigations necessary); R3, probably benign (deepening or close inspection); R4, suspicion (histological finding); and R5, positive (histological finding).⁵⁷

Although simpler, this classification does not speak the same language for everyone, and what is R3 for one radiologist might be R4 for another and vice versa. In our opinion, it would be advisable to manage mammographic signs based on their PPV for carcinoma as follows: spiculated opacity with calcifications (PPV = 81%); spiculated opacity (PPV = 60%); blurred opacity (not regular, PPV = 40%); regular opacity with calcifications (PPV = 15%); regular opacity (PPV = 4%); distortion and microcalcifications (PPV = 12%); distortion (PPV = 8%); solitary microcalcifications (PPV = 21%); and asymmetric density (PPV = 2%).⁵⁸

Mammography, like all diagnostic techniques, has limitations related to the method itself, machinery (91% of which are outdated), difficulties in interpreting breast tissue characteristics, or because the lesion is so small that it is not recognizable. Mammographic density is the real challenge of early diagnosis. Density is an indicator of a higher risk for breast cancer.⁵⁹ Mammographic sensitivity for breast cancer significantly decreases with increasing breast density and is higher in older women with fatty breasts. Hormonal status has no significant effect on the effectiveness of screening regardless of breast density.

The limitations and sensitivity of mammography manifest as interval carcinomas. Interval carcinomas are cancers that arise after a negative diagnostic test and before the subsequent test. They are more frequent in young women due to dense breast tissue, which does not allow for a detailed analysis of individual structures by mammography, and their frequency decreases with age.⁶⁰ In women with high-density patterns, the incidence of interval cancers is higher. It is therefore advisable to use ultrasound routinely to identify mammographically occult cancers that are not visible on radiological examination.⁶¹ Interval cancers are determined by the natural history of disease, by the frequency of examination (1 or 2 years), and by the sensitivity of mammography. They can be classified as false negatives (diagnostic error), minimal signs of cancer (hindsight), occult (not visible), and true interval cancer. Meanwhile, false negatives depend on the following: perception error, where the anomaly is present but not recognized; interpretation error, where the anomaly is present, seen, and considered benign; and error from incorrect technical acquisition due to poor breast positioning, lack of contrast, or inadequate compression.

Defining interval cancer as an error is not always correct. The error is present only in 20–25% of cases.⁶² In fact, there are some breast carcinomas that, due to intrinsic limitations, are not detectable. Occult interval carcinomas are not detectable due to intrinsic limitations, very small cancer, very deep cancer, and cancer in a dense context.

There is no breast specialist, radiologist, or ultrasound techni-

cian, no matter how skilled, who can surpass these limitations. Also, the advent of digital mode, contrary to initial expectations, has not overcome this limitation. More advanced techniques in the field of digital mammographic imaging, such as tomosynthesis, show strong potential in this regard. One method to reduce interval cancers is to repeat the mammogram annually rather than every two years. To reduce interval cancers, a second mammographic reading or CAD would be useful in screening. The additional diagnostic value of a second reading by a radiologist or the use of CAD is around 9%. CAD identifies the regions of interest, which would be the areas of greatest interest for the mammogram reader. By increasing the sensitivity by 10%, the rate of diagnostic deepening increases, and it has low specificity.⁶³

Some studies indicate that women with high breast density have a higher risk of breast cancer, likely due to the high content of glandular structure present in breast tissue.⁶⁴ In cases of dense breast tissue, the sensitivity of mammography is lower compared to women with fatty breast tissue because the baseline density of the mammary parenchyma can mask the presence of small cancers. Therefore, the mammography PPV largely depends on the breast density. There have essentially been two attempts to classify density. One is the ACR's BI-RADS (Table 2). The other is Wolfe's classification (Table 3).⁶⁵ Thus, breast density has a PPV for cancer onset and for the risk of interval carcinomas and local recurrences.⁶⁶ For this purpose, it would be advisable, in daily practice, to inform women about diagnostic issues and expected outcomes.⁶⁷

Screening mammography is now recommended for all women over 40 years of age. In this group, mammography should be performed every 1–2 years and then annually after the age of 50 years. In November 2009, the USPSTF updated their recommendations for routine mammography for women aged 40–49 years. USPSTF has examined evidence on the effectiveness of the following five screening modalities in reducing breast cancer mortality: analog mammography using film, clinical breast examination, breast self-examination, digital mammography, and MRI.

The USPSTF recommendations are as follows: (1) screening mammography in women aged 40 to 49 years, and the decision to start regular biennial mammographic screening before the age of 50 should consider the woman's judgment, including the patient's

Table 3. Classification of the parenchyma according to Wolfe

Breast density type	Appearance	Diagnostic reliability	%
I	adipose	maximum	>95%
II	fibroglandular	elevated	<90%
III	heterogeneous	reduced density	<70%
IV	marked	low density	<60%

decisions regarding specific benefits and risks; (2) biennial mammography screening for women aged 50 to 74 years; (3) the current evidence is insufficient to evaluate the cost-benefit of mammography screening in women aged 75 and older; (4) the current evidence is insufficient to assess the cost-benefit of clinical breast examination beyond mammographic screening in women aged 40 and older; (5) physicians should teach women how to perform breast self-exams; and (6) the current evidence is sufficient to assess the additional benefits and risks of digital mammography or MRI instead of analog mammography as a screening modality for breast cancer.⁶⁸

In response to the new USPSTF recommendations, the ACR and the Society of Breast Imaging released a joint statement that included the following benefits and concerns of annual screening mammography starting at age 40 years: (1) it is noted that mammography has reduced breast cancer mortality rate in the US by 30% since 1990, which is only a small benefit; (2) based on data on the performance of screening mammography as it is currently practiced in the US, an invasive cancer is diagnosed for every 556 mammograms performed; (3) in cases of mammography performed every two years in women aged 50–74, 19–33% of cancers that could be detected with annual screening are interval cancers; (4) if screening mammography started at 50 years old, we would sacrifice 33 lives for every 1,000 women screened, who could have been saved if screening had started at 40 years old; and (5) 85% of all abnormal mammograms only require additional images to clarify if cancer may be present (or not).⁶⁹

Only 2% of women who undergo screening mammograms have a biopsy. USPSTF data show that the biopsy cost is lower among younger women. In summary, mammography has limitations under the following conditions: opaque or glandular breasts; marginal location of cancer; low intrinsic density (opacity) of cancer; very small cancer; regular contours of some cancers; and defects of the equipment and errors in the execution of the examination.

Despite mammography being considered the main technique for early diagnosis, studies indicate a non-negligible percentage of false negatives ranging from 10% to 30%. According to data from the Breast Cancer Detection Demonstration Project, the false-negative rate of mammography is about 8–10%. The 30% interval cancer makes it more likely that the false-negative rate is higher. About 1–3% of women with a clinically suspicious abnormality, a negative mammogram, and a negative ultrasound may have breast cancer (hidden cancer).⁷⁰ The possible causes of undiagnosed breast cancer are dense parenchyma obscuring the lesion, poor positioning or incorrect technique, perception error, misinterpretation of a suspicious presence, mild malignancy characteristics, and slow growth of a lesion. Birdwell *et al.*⁷¹ conducted a multicenter study and found that, in previous mammograms with unresponsive cancer, 30% of the lesions were calcifications, with 17% of the 49 clusters being pleomorphic. About 70% were nodular lesions, with 40% being spiculated or irregular. For calcifications and masses, the most frequently suggested reasons for potential underdiagnosis were dense breasts (34%).⁷¹

Women who have had previous surgery for breast cancer may present breast cancer with screening mammography. If a woman has had a total mastectomy, the other breast requires annual follow-up because she is still at higher risk of developing breast cancer. If she had a subcutaneous mastectomy or a partial mastectomy, she requires a follow-up mammogram. The first mammogram is best performed six months after surgery to provide a baseline for the new postoperative and radiotherapeutic changes. Subsequently, the mammogram can be performed every 6–12 months for screen-

ing and follow-up.^{72,73} Women with breasts treated with prosthetic implants can be a special challenge. Special four-view mammograms can be performed to evaluate the breast. The implant must be pushed aside so that the underlying breast tissue can be exposed. MRI can be particularly useful for detecting breast cancer and silicone implant rupture in this group of patients.^{74,75}

Screening mammography offers the possibility of avoiding breast cancer, but it carries the risk of false-positive results, leading to overdiagnosis of breast cancer and unnecessary treatments. Welch and Passow have sought to quantify the risks and benefits of screening mammography so that the risks and benefits can be shared with women to help them make informed decisions. Three outcomes related to screening mammography were evaluated for women starting mammography at ages 40, 50, and 60 years: reduction of deaths from breast cancer; false positives (including subsequent biopsies); and overdiagnosis and overtreatment.

These results are reported in terms of 1,000 women screened annually over a period of 10 years. Due to statistical variability and uncertainty, as well as heterogeneity of the studied populations, the results are reported within a range of lower and upper limits for each outcome. Data were obtained from randomized clinical trials of screening mammography. Reduction in deaths from breast cancer and measurement of the mortality rate were carried out five years beyond the first 10 years, based on the assumption that reduction in mortality extends for 15 years from the start of screening. False-positive results were classified as a call for further tests or a recommendation for biopsy. These are the results for the individual age groups: (1) out of 1,000 40-year-old women, subjected to annual mammograms for 10 years, 1–16 women will avoid dying from breast cancer; 510–690 women will have at least one false-positive test, with 60–80 biopsies; and up to 11 women will undergo overdiagnosis and overtreatment and be unnecessarily treated with surgery, radiotherapy, or chemotherapy; (2) out of 1,000 women aged 50 years, subjected to annual mammograms for 10 years, 3–32 women will avoid dying from breast cancer; 490–670 women will have at least one false-positive test, with 70–100 undergoing a biopsy; and 3–14 women will be over diagnosed and unnecessarily treated with surgery, radiotherapy, or chemotherapy; and (3) out of 1,000 women aged 60 years who undergo annual mammograms for 10 years, 5–49 women will avoid dying from breast cancer; 390–540 women will have at least one false-positive test, with 50–70 undergoing a biopsy; and 6–20 women will undergo overdiagnosis and overtreatment and be unnecessarily treated with surgery, chemotherapy, or radiotherapy.¹²

False-positive results can occur when benign microcalcifications are considered malignant. Tissue summation can appear as a distortion of the parenchyma, which can be mistakenly defined as malignant tissue. A localized benign lesion may show suggestive signs of malignancy, along with other findings, such as an irregular or lobulated border. Some types of cancer (for example, mucinous carcinomas) can instead have well-defined margins and mammographic characteristics suggestive of benignity. A ductogram, or galactography, is sometimes useful for determining the cause of nipple discharge. In this procedure, a small amount of contrast medium is injected into a nipple duct to outline the shape of the duct on a radiographic image and show if a mass is present inside the duct.^{76–79}

There is no doubt that the most natural and effective way to remove the so-called “structural noise” in mammography is to physically separate the various anatomical structures of the breast. Mammography indeed represents a two-dimensional (2-D) projection of a three-dimensional (3-D) structure, so that, geometrically,

tissues belonging to different planes appear superimposed in the radiographic image. Tomographic technology has reached maturity even for the early diagnosis of breast cancer, for which dedicated systems are in the phase of clinical application.^{80,81}

Unlike the “traditional” diagnostic exam, which produces only two 2-D images (one from above and one from the side), 3-D mammography captures multiple images from different angles. These images are then combined to form a 3-D reconstruction of the breast, allowing radiologists to examine tissues with greater precision. During tomosynthesis, the image acquisition process is like that of traditional mammography. The patient is positioned in front of a mammogram machine, and the breast is compressed between two plates. The mammogram then rotates around the breast, acquiring a series of low-dose images from different angles.⁸² The acquired images are processed by a computer to create a series of thin “slices” of the breast, like the result of a computed tomography (CT) scan. This allows radiologists to examine each layer of breast tissue, reducing the tissue overlap that can hide lesions in traditional mammography.⁸³ Its purposes are to identify lesions that currently escape digital mammography, reducing interval cancers; to reduce the number of false positives; and to impact the recall rate in screening programs.

Until recently, performing a 3-D mammogram involved additional exposure to X-rays compared to a 2-D mammogram. Today, however, thanks to the C-view software, 2-D mammography and tomosynthesis can be performed with the same dose as “low-dose” mammography, thus minimizing the patient’s exposure to X-rays. The images from tomosynthesis are examined together with the 2-D images and are essential for breast evaluation, comparison with previous exams, and the rapid recognition of microcalcifications.⁸⁴

The most important difference with mammography is the use of a moving X-ray source in tomosynthesis. During a tomosynthesis exam, the X-ray source moves in an arc above the breast and acquires multiple projections. In the end, numerous images are obtained, each showing a layer of the breast. Tomosynthesis can be acquired as an additional image to the usual mammograms, or it can be acquired on its own. This latter protocol is possible because images very similar to usual mammograms can be reconstructed from the tomosynthesis data set. These so-called “synthetic mammograms” can avoid the need to acquire the original mammograms. According to the device used, radiation exposure is equal to or slightly higher than that of a mammogram, but it is still within the limits recommended by international radiation safety guidelines. The results of several studies comparing only mammography with tomosynthesis mammography have shown that tomosynthesis can significantly increase cancer detection by up to 30–40%.⁸⁵

Tomosynthesis is already used as a screening method in the US. In Europe, only a few centers perform tomosynthesis in organized screening programs, especially within the context of research programs approved by ethical committees. The results of these studies are promising. Three prospective studies have shown that digital breast tomosynthesis used as an additional test or alternative to conventional digital mammography allows for superior diagnostic performance compared to mammography alone. Overall, tomosynthesis provides an increase in the detection rate from 0.5 to 2.7 per 1,000 screened women, as well as a reduction in the recall rate from 0.8 to 3.6 per 100 screened women. All these aspects will likely confer tomosynthesis the status of future routine mammography, even in the context of screening.⁸⁶ However, before introducing tomosynthesis in breast cancer screening outside of ethically approved trials, there should be evidence of a statistically significant and clinically relevant reduction in the interval cancer

rate. This caution is due to the need to avoid an increase in costs. The initial results of a reduction from 0.7 to 0.5 cancer intervals per 100 screened women were recently reported by a large study in the US, but further evidence is needed.^{87–91}

During breast examinations performed outside the screening environment, it is the radiologist’s choice to perform only mammography, use tomosynthesis and/or ultrasound, or to perform tomosynthesis without standard mammography and obtain reconstructed synthetic mammography. This decision is based on various aspects: breast characteristics, the availability of previous exams, the availability of technology, and the radiologist’s preference regarding the specific case. If a woman is invited to participate in a screening program where tomosynthesis is proposed in the context of a study or as a routine practice, she should consider that the potential benefits of tomosynthesis in terms of increased cancer detection and reduced recall rate should outweigh the negligible increase in radiation dose. Published clinical studies have shown that tomosynthesis has demonstrated an increase in sensitivity and specificity with a reduction in false positives ranging from 17% to 37%, allowing for the recognition of neoplasms not visible with 2-D mammography by 27% to 40% more depending on the studies and better defining any present alterations.⁹²

In tomosynthesis, the radiation dose is well below the safe dose, substantially like digital mammography but far lower than analog mammography. C-view tomosynthesis allows for 3-D mammography execution with reconstruction through a mathematical algorithm of a 2-D image. In tomosynthesis, the anatomic details present in the examined plane appear perfectly “in focus” and therefore with much greater visibility (better signal-to-noise ratio). Layered reconstruction in tomosynthesis reduces or eliminates problems caused by tissue overlap, although the limited rotation angle (compared to the 360° rotation of CT) does not allow for complete cancellation of the details contained in the planes above or below the area of interest (“drag shadows”).^{93–95}

Tomosynthesis offers numerous advantages over traditional mammography, making it a preferred choice for many patients and healthcare professionals. These benefits are evident and improve the overall effectiveness of mammographic screening. One of the main advantages of tomosynthesis is its ability to detect breast cancer at an early stage. Studies have shown that tomosynthesis increases the breast cancer detection rate compared to traditional mammography, especially in cases of dense breasts, where tissue overlaps can make it difficult to identify abnormalities. Another significant advantage of 3-D mammography is the reduction of false positives. Since tomosynthesis allows for a clearer and more detailed visualization of breast tissue, radiologists can better distinguish between benign and malignant lesions. In this way, the need for further diagnostic tests is reduced, with clear results for patients right from the start, also decreasing anxiety.^{96,97}

3-D mammography provides a detailed view of the breast, allowing for a more accurate diagnosis. Radiologists can identify the nature of lesions with greater certainty, thereby improving patients’ clinical management. This level of detail is particularly useful for planning surgery and treatments. Tomosynthesis is recommended for all women who need mammographic screening. It is particularly useful for women with dense breasts, a family history of breast cancer, or previous breast biopsies. Consulting a physician can help determine if 3-D mammography is the right choice.^{98–100} A recent study analyzed the results of 12,631 exams interpreted using only mammography vs. mammography plus tomosynthesis. Researchers found that with mammography plus tomosynthesis, there was a 31% increase in the cancer detection rate, the false-

positive rate was 13% lower, and there was a 26% increase in the detection of high-grade lesions.^{101,102} In another study, investigators concluded that adding 3-D to a screening exam reduced recall rates by 40%.¹⁰³

In summary, the advantages of 3-D digital mammography with tomosynthesis are as follows: more accurate analysis by eliminating artifacts from the overlap of fibroglandular tissue; increasing spatial resolution; reduced false negatives and false positives; higher detection rate of invasive carcinomas, but also noninvasive ones; reduction in the number of recalls; higher PPV; reduction in interval cancers; and better diagnostic concordance index.

The very latest development is CAD, which uses markers to indicate areas of greatest interest, like dense ones.¹⁰⁴ According to the ACR Imaging Network, about 40% of all women undergoing screening mammography have dense breasts. So, there is the problem of breast cancer masking due to breast density. That's why there is a higher risk of breast cancer in women with dense breasts, as we have said before.¹⁰⁵ To solve this problem, some centers have implemented software for breast density measurement, which is a breast density assessment tool to improve early diagnosis among women with dense breasts. This software automatically generates objective and automatic measurements of volumetric breast density values with a classification system correlated with ACR's BI-RADS breast density classifications. It has been approved by the Food and Drug Administration for all digital mammography units, and integration with other digital mammography systems, CAD, and mammography reporting solutions is also underway. The software provides a more objective estimate of breast density because it is a volumetric measurement. There is indeed a good correlation with the visual interpretation. It has given a certain consistency to the entire density determination process.¹⁰⁶

A recent study proposes the use of a traditional mammogram enhanced by a sensitive contrast medium to detect and evaluate breast cancer. At the center of this work is mammography with a digital mammography machine using a contrast agent, so-called contrast enhanced spectral mammography (CESM), which has been recently introduced. This combines traditional mammographic images with information derived from the administration of an iodinated contrast medium, similar to breast MRI with contrast medium. The authors particularly focused on women with lobular invasive carcinoma, which accounts for 10–20% of all breast cancers. It is a type of cancer that tends to remain silent until it is in an advanced stage and, therefore, is often diagnosed late, also because digital mammography is less effective in this case, especially in women with dense breast tissue. The ability of this instrumentation to detect this form of breast cancer ranges from 57% to 81%. It even seems that in women with particularly dense breast tissue, the efficiency of the mammogram drops to 30%. From here came the idea of using the new CESM technology, which, among other things, takes only 7–10 minutes and is well accepted by patients.

The diagnostic accuracy of CESM is like that of breast MRI with contrast medium, in accordance with the literature data. Similar to other imaging methods that use contrast, CESM allows for the identification of cancer lesions by detecting pathological hypervascularization due to cancer neoangiogenesis. In particular, the study demonstrated that this technique could even diagnose hidden cancer. Normally, this lesion is preceded by a pathological lymph node in the axillary region or, in rarer cases, by a bone lesion. These are cancers for which, normally, MRI is used. Furthermore, by highlighting cancer vascularization, this technique should also allow for local staging of invasive lobular carcinomas to optimize surgical treatments and reduce recurrence risk. In the

case studied, CESM and MRI showed the same ability to identify occult breast cancer. The important implication of CESM's ability to identify this type of cancer is the possibility of avoiding the very costly and invasive MRI-guided biopsy in favor of the CESM-guided biopsy.^{107–110}

In summary, the validity of mammography lies on highlighting the characteristics of the nodule, microcalcifications, any adenopathy, high sensitivity in fatty breasts, and identification of nonpalpable lesions through stereotaxis.^{111,112} Nevertheless, every woman must know that various diagnostic tests, even if repeated, cannot prevent breast cancer onset but can detect it in the early stages of its development. The early diagnosis of breast cancer allows, in many cases but not all, a reduction in mortality with the use of less aggressive therapies. In fact, about 20–30% of breast cancers are not visible on a mammogram, so it is sometimes necessary to supplement the examination with ultrasound and breast examination. The integration of mammography with other exams (e.g., ultrasound, elastography, and needle biopsy) is especially useful in the increasingly frequent cases of “dense breast” in the mammographic examination. Despite the execution of multiple diagnostic tests, approximately 10% of breast cancers do not allow themselves to be recognized and only become evident in subsequent check-ups. Interval cancers are those lesions that appear after a mammogram has been deemed negative and before the subsequent one scheduled to take place one or two years later. To avoid false reassurances, it is therefore necessary to periodically check the breast and, in case of doubt, consult the physician. It is important to adhere to the “interval check frequency” to timely detect those cancers that, although present, are not highlighted. In some cases, it can happen that the patients undergo surgery for lesions that seem suspicious but then turn out to be benign.^{113–115}

Ultrasound

Breast ultrasound is used in medicine for the morphological study of both male and female breasts. Echotomography is a diagnostic technique based on ultrasound in which a probe captures a wave of refraction after it has passed through a part of the body. A dedicated computer subsequently reconstructs a well-defined image based on the collected data. To date, it is a method that does not present side effects and/or contraindications. Not being based on radiation, it is also recommended for young individuals as well as during pregnancy. The exam is completely painless and noninvasive. A water-based gel is applied on the skin to prevent the transducer (probe) from interfacing with the air.

As a support or otherwise complementary to mammography, ultrasound has become essential in recent years for the early diagnosis of breast cancer, especially thanks to the new high-frequency sound wave probes (9–13 MHz). Certainly, as useful, if not more so, than mammography for the study of benign breast pathology (fibroadenomas, lipomas, and cysts), it is today an excellent tool for preventive diagnostics and therefore recommended once a year. The simple ultrasound examination can be combined with a Doppler color study, which, through sophisticated software, allows for better understanding of a diagnostic suspicion by studying the vascularization of a lesion.

The most recent evolution is represented by the 3-D technique, which, unlike the classic 2-D image, is based on the acquisition, through a special probe, of a “volume” of examined tissue. The volume to be studied is acquired and digitized in fractions of a second, after which it can be subsequently examined either in 2-D mode, with the examination of countless “slices” of the sample

(along the x, y, and z axes), or in volumetric representation, with the examination of the tissue or organ to be studied, which appears on the monitor as a solid that can be rotated along the three axes. In this way, its true appearance in three dimensions is highlighted with clarity. The real-time method incorporates the “movement” effect, such as the fetus moving in the amniotic fluid, into all of this.

An application of the 3-D technique is represented by the automated breast ultrasound system. This 3-D ultrasound technology represents a screening option for women with dense breast tissue. It can improve the early diagnosis of invasive breast cancer compared to the use of tomosynthesis alone. The 3-D volume and multiplanar access allow for an accurate, noninvasive analysis of the breast cancer before proceeding to the global view of the breast, also ensuring the reproducibility of the examination.^{116,117}

In ultrasound, an intravenous contrast agent consisting of sulfur hexafluoride microbubbles can be used, which increases the echogenicity of the blood: this technique can be used both for vascular ultrasound studies and for characterizing lesions of abdominal organs (especially the liver and the kidney, and sometimes also the spleen and the pancreas).¹¹⁸ The ultrasound contrast agent has few contraindications (sulfur allergy and ischemic heart disease) compared to those used in CT and MRI. Therefore, it can be used as a less invasive method, also considering the absence of ionizing radiation and radiofrequency or magnetic fields. This technique was discovered by Dr. Raymond Gramiak in 1968, and called “contrast-enhanced ultrasound”.¹¹⁹ This technique is particularly used in echocardiography and radiological ultrasound.¹²⁰ Microbubbles, due to their diameter, remain confined within blood vessels, unable to escape into the interstitial fluid. For this reason, ultrasound contrast agents are completely intravascular, a characteristic that makes them an ideal means for revealing the microvascularization of organs during diagnostics.

A typical clinical use of contrast-enhanced ultrasound consists of locating hypervascular metastatic cancers, which exhibit a faster contrast uptake (kinetics of microbubble concentration in the blood) compared to the surrounding healthy biological tissue.¹²¹ Furthermore, the use of microbubbles specifically engineered to attach to cancer capillaries through the biomolecular expression of cancer cells, suggests a future application of contrast-enhanced ultrasound to identify cancers at a very early stage.^{122–126} Other clinical applications of contrast-enhanced ultrasound include, for example, the delineation of the left ventricle during echocardiography to visually inspect the contractility of the myocardium following a heart attack. Finally, applications have also emerged in the quantitative analysis of perfusion to identify the patient’s response to early-stage anticancer treatment, to determine the best oncological therapy.^{127–130}

In oncology, the use of contrast-enhanced ultrasound has been designed to be a helpful tool in the diagnosis of cancer tissues, facilitating the characterization of the type of tissue (benign or malignant).^{131,132} It is a computational method for analyzing a time series of ultrasound images with contrast medium (in the form of a digital video clip) acquired during the patient’s ultrasound examination.^{133,134} Once the cancer area is delineated, two stages of signal analysis are applied to the pixels in the cancer area: (1) calculation of the distinctive feature of vascularization (difference in contrast absorption compared to the surrounding healthy tissue); and (2) automatic classification of the distinctive vascularization trait through a single parameter, coded with one of the following colors: green, for a higher continuous signal (greater contrast absorption compared to the surrounding healthy tissue); blue, for a

less elevated continuous signal (lower contrast uptake compared to the surrounding healthy tissue); red, for a rapid increase in the signal (contrast absorption that occurs earlier than the surrounding healthy tissue); or yellow, for a rapid decrease in the signal (contrast absorption that occurs later than in the surrounding healthy tissue).

Once the signal analysis for each pixel is completed, a color map of the parameter is displayed on the screen, summarizing the vascular information of cancer in a single image, called a parametric image.¹³⁵ This parametric image is interpreted by the specialist based on the predominant color in the lesion: red indicates a suspicion of malignancy, and green or yellow indicates a high probability of benignity. The benefit of this method is to avoid a systematic biopsy of benign lesions or the patient’s exposure to a CT scan. This method has been shown to be effective for the characterization of liver cancers.¹³⁶ In a cancer screening context, this method may potentially be applicable to other types of cancers, such as breast or prostate cancers.¹³⁷

Ultrasound is an examination that can be applied to women of any age, it can measure the size of the neoplasm, and it can differentiate solid tissues from liquids. In fact, it is especially useful in distinguishing between solid masses (which may be cancerous) and cysts (which are benign). It is recommended for women with dense breast tissue, where mammography may be less effective. Ultrasound, on the other hand, has a low specificity and does not detect microcalcifications, which are often early signs of cancer. Furthermore, it may result in false positives, requiring further testing. For these reasons, it is not generally used for routine screening but rather as a supplementary diagnostic tool. In fact, this method is considered a basic or screening examination compared to more complex imaging techniques such as CT, MRI, and angiography. Moreover, ultrasound is an operator-dependent procedure, as it requires manual dexterity and observational skills, in addition to image culture and clinical experience.^{138–141}

Magnetic resonance imaging

MRI is an advanced medical imaging diagnostic technique that uses a powerful magnetic field and radio waves, harmless to health, with or without the aid of a contrast agent injected intravenously, to provide detailed and 3-D high-quality images of the anatomy of any part of the body, including breast tissue. MRI has become a fundamental diagnostic tool, finding numerous applications also in the field of women’s health. This advanced imaging technology allows physicians to obtain highly detailed images of breast tissue, providing crucial information for the early and accurate diagnosis of breast pathologies, especially those of a malignant neoplastic nature. It is an alternative or complementary examination to the more traditional techniques (mammography and breast ultrasound) that allows for the extremely accurate identification of even very small nodules, often impalpable and not detectable with traditional methods, by studying their vascularization dynamics and not limited by the density of the mammary gland, which is the limitation of mammography. Breast MRI indeed allows for identification of malignant nodules because these are differently vascularized compared to normal breast tissue and benign nodules. Unlike mammography, breast MRI does not use ionizing radiation, making it a safe choice for patients, while compared to ultrasound techniques, it offers a much higher spatial resolution. Moreover, being a “multiparametric” imaging technique, it provides multiple pieces of information about tissue characteristics, specifically breast glandular tissue and the specific pathologies related to it, allowing for more

accurate analysis and more targeted diagnoses.¹⁴²

Breast MRI can identify a wider range of cancers, including those that are occult at mammography and/or ultrasound (mammographic screening can identify about 4–6 breast cancers per 1,000 women, while ultrasound can identify 2–4 cancers not visible on mammography per 1,000 women undergoing mammographic screening). It has the advantage of preferentially identifying those intermediate and high-grade carcinomas that are more significant from a biological standpoint. For this reason, it has shown significant progress in breast cancer diagnosis and is recognized as the most sensitive method available today in the field of breast diagnostics for detecting breast cancer.^{143,144} In fact, in the field of imaging diagnostics, breast MRI represents an advanced and highly specialized frontier. This exam is not part of the routine screening for breast cancer but is used on specialist indications to further investigate diagnostic doubts raised by first-level exams such as tomosynthesis mammography, breast ultrasound, and breast examination. So, breast MRI is a second-level technique which, due to its high diagnostic sensitivity characteristics, is not applicable to all patients but only to selected cases, according to precise indications defined by international medical scientific literature. The main indications for breast MRI examination are as follows: (1) women at high genetic-familial risk for breast cancer; (2) search for occult metastatic primitive carcinoma of suspected mammary origin with negative traditional tests; (3) search for multicentricity, multifocality, and bilaterality in cases of neoplasms already diagnosed with traditional techniques and candidates for conservative surgery (quadrantectomy); (4) evaluation of breast neoplasms treated with neoadjuvant chemotherapy; (5) follow-up after conservative surgery, to distinguish between recurrence or scar tissue; (6) evaluation of women with prostheses; and (7) discrepancy between investigations and/or difficult interpretation of traditional diagnostic investigations (ultrasound and mammography).¹⁴⁵

In some cases, the examination is performed using an intravenous contrast agent. In others, it is done without it. The use of the contrast medium, generally gadolinium, classifies it as an invasive examination. An exception to this rule is breast MRI for implants, performed without a contrast agent. MRI with contrast agents is performed in the following cases: (1) monitoring of high-risk patients—women with high familial risk of developing breast cancer, combined with the presence of specific mutations in breast cancer genes (BRCA1 and BRCA2); (2) additional investigations—to clarify doubts arising from mammographic or ultrasound examinations; (3) surgical planning—before surgical intervention, for the local staging of cancer and to assess the possible existence of additional foci of neoplasia not visible with conventional examinations (mammography and ultrasound); and (4) post-operative evaluation—in patients who have already undergone surgery for breast cancer, where there are doubts between cancer recurrence or surgical scar resulting from one or more previous surgeries.

Available literature suggests that the sensitivity of contrast-enhanced breast MRI in detecting cancer is significantly higher than that of traditional mammography or ultrasound and is generally considered to be around 94%.¹⁴⁶ The specificity is modest (between 37% and 97%), so a positive result on MRI should not be interpreted as a definitive diagnosis.¹⁴⁷ There are optimal periods that allow for reduction in false positives. In premenopausal women, it is preferable to conduct the investigation between the fourth and the fourteenth day of the menstrual cycle (even during estrogen-progestin therapy) to avoid false positives due to breast density, while for postmenopausal patients no temporal restriction is necessary, except for women who are undergoing hormone re-

placement therapy, who should wait at least four weeks after treatment has been suspended.¹⁴⁸

Breast MRI study under basal conditions only, without the use of contrast medium, is used for (1) the evaluation of prosthetics (e.g., to check the integrity of aesthetic or reconstructive breast implants after oncological surgery); (2) complications related to prosthetic surgery (e.g., to detect any potential intracapsular or extracapsular ruptures, silicomomas, and prosthetic contractures); and (3) patients with known hypersensitivity to paramagnetic contrast agents.^{149,150}

It is appropriate to clarify that contrast agents used for MRI investigations of the breast or other body areas are extremely safe drugs and are usually very well tolerated. Obviously, every rule has its exceptions: patients with allergies, possibly multiple, to drugs or metals must be evaluated to determine compatibility with the paramagnetic contrast agent to be used. In summary, the choice between MRI with or without contrast agent depends on the specific clinical and diagnostic needs of each case. Consulting a specialist physician is, therefore, essential to determine the most appropriate approach.¹⁵¹

To perform this examination, a high magnet field machine is used, shaped like a cylinder with a bed inside. In the case of breast MRI, the examination table is equipped with special cup-shaped cavities where the breasts are positioned. After depositing personal items, particularly those sensitive to magnetic fields, such as watches and credit cards, the nurse prepares the venous access by inserting a cannula needle into a vein in the woman's arm, through which the contrast medium will be administered during the examination. Subsequently, the woman, with her chest exposed, is positioned by the technician in a prone position with her breasts inside the appropriate cavities on the table that slides into the "magnet." The execution of breast MRI utilizes a specific coil, an accessory designed specifically for the breast, which envelops both breasts to achieve better spatial resolution. The use of a dedicated field of view for each individual breast allows for an excellent morphological evaluation of lesions, providing a complete overview of the breast. Unlike older generation MRI systems, the new machines are shorter and have wider tunnels, significantly reducing the feeling of claustrophobia that some patients experience. Inside the apparatus, a strong magnetic field is generated that alters the spatial position of the hydrogen protons present in the body. Subsequently, with the delivery of radio wave pulses, proton oscillation phenomena are stimulated. When the radio waves are interrupted, the protons release the accumulated energy, which is detected by a receiving coil and converted into images by the computer.¹⁵²

MRI is a method that does not use ionizing radiation but high-intensity electromagnetic waves to obtain high-quality 3-D images. Unlike X-rays, which cause ionization phenomena in atoms, radio waves, of the same type used in communications, do not cause dangerous alterations in the atoms and molecules of the body. This is why MRI investigations can also be performed on pregnant patients after the first trimester of gestation. It is a non-invasive and painless diagnostic test for the patient and lasts about 20–30 minutes. The patient must remain lying face down with the breast inserted into special cavities in the resonance coil. A technician offers support via video and intercom for any eventuality. Furthermore, to reduce discomfort caused by noise, the patient wears headphones and receives a disposable gown for comfort. Since ionizing radiation is not used, the woman can engage in any activity immediately before the examination and can be in contact with children and vulnerable individuals immediately after. It is essential that breast MRI is performed on high magnetic field machines (1.5 or 3 Tesla). Low-field (0.5 Tesla) or open mid-field (1 Tesla)

MRI are indicated only for the study of prostheses and for patients who cannot undergo high-field MRI (for example, claustrophobic patients).¹⁵³

The examination is conducted by a specialized radiology technician under the supervision of a radiologist-senologist and with the presence of an anesthetist for the management of contrast medium administration and patient monitoring. In the case of an examination performed with contrast medium, preparation requires that the patient fast for at least six hours and provide a creatinine test to assess renal function. This allows physicians to safely authorize gadolinium use.¹⁵⁴

Contraindications are the same as for any MRI exam. Breast MRI is not suitable for patients with cardiac pacemakers or stimulators with metal components or ferromagnetic implants in breast expanders, orthopedic nails or screws, nonremovable metal dental and bone prostheses, or vascular and intracranial clips that are not compatible with the strong magnetic field generated by the machine. Chest width or excess abdominal fat can also limit the execution of the exam, although there are MRI machines with wide openings for these specific cases.^{155,156}

In conclusion, breast MRI, which is part of a broad diagnostic mosaic, offers an extremely accurate diagnosis in patients with very specific requirements. The advantages of breast MRI are that it improves the accuracy of conventional imaging (mammography and breast ultrasound) in assessing the extent and size of cancer, with the identification of additional malignant lesions or in evaluating multifocal and multicentric cancers during loco-regional staging. And thanks to an even more innovative technology, represented by the use of 3-Tesla magnetic field scanners, there is an increase in spatial and temporal resolution with corresponding improvement in the identification of the lesion. Breast MRI is the method of choice in the study of young women genetically predisposed to breast cancer or in cases of suspected multifocal and multicentric disease, or when there is a significant discrepancy between traditional diagnostic investigations and clinical evaluation, and in women with implants in cases of suspected implant rupture.^{157,158} Breast MRI therefore represents an advanced imaging technology that has allowed for a significant evolution in the modern diagnosis of breast diseases. Its ability to provide detailed and accurate images of breast tissue is considered of fundamental importance for the correct and early diagnosis of breast neoplastic lesions. Unfortunately, these lesions are extremely frequent in the female population and are also present, albeit in extremely smaller percentages, in the male population. Statistics tell us that 1 in 100 cases of breast cancer affects individuals of the male sex.¹⁵⁹

Breast MRI is not part of routine exams for diagnosing breast cancer, but in some selected cases it can become decisive. For the early diagnosis of breast cancer, it is important to emphasize the significance of the famous and historic triad: examination, mammography, and breast ultrasound. These evaluations are complementary to each other in most cases and sufficient for a diagnostic finding. The combination of these three assessments, in fact, allows for the early diagnosis of breast cancer in asymptomatic women. But it is necessary to keep in mind that clinical examination and self-palpation are crucial for prevention. MRI is used only in selected cases.^{160,161} It is indicated as an annual check-up in association with mammography and ultrasound for monitoring a small group of patients, about 5–10%, with a high risk of developing familial or hereditary breast cancer, accompanied by the presence of specific mutations in BRCA1 and BRCA2 genes.^{162,163}

MRI is also indicated in preoperative evaluation and is targeted once a breast lesion (such as a nodule) is confirmed to exclude the

presence of other abnormalities. This step is important for determining the most appropriate type of surgical intervention. Again, the examination becomes fundamental whenever there is a discrepancy between the outcome of clinical and instrumental evaluation, particularly for the search for what is defined as a “hidden primary lesion or cancer of unknown primary site syndrome”. These are the cases where cytological/histological examination has revealed a pathological condition affecting a lymph node in the axillary cavity, but the mammogram and ultrasound results are normal. The examination is also an excellent tool for studying breast implants (in this unique case without the use of contrast medium).^{164,165}

Breast MRI can also become an important test for postoperative monitoring. In fact, breast MRI is used as a second-level examination whenever it is necessary to further investigate the scars of one or more surgical interventions if there is an ultrasound or mammographic suspicion of local recurrences. MRI can also be indicated for evaluating the effect of chemotherapy to be administered before surgery in advanced cancer or when a recurrence of the disease is suspected.^{166,167} Ultimately, breast MRI is a very powerful diagnostic tool with high image quality that allows for the identification of even very small breast nodules, which are often impalpable and invisible with traditional methods. It is important, however, to remember that the test in women of childbearing age should be performed from the fourth day to the fourteenth day of the menstrual cycle to avoid affecting the result.^{168–173}

Thermography

Breast thermography consists of studying the heat emitted by the breast and detected by thermographic probes. Thermography can be performed using an infrared camera, called telethermography, or using a plate placed in contact with the breast, called contact thermography. The last evolution of contact thermography is the current clinical procedure called dynamic angiotermography (DATG). Since thermography is a technique that does not emit ionizing radiation, various studies have been conducted to evaluate the possibility of using it as a screening test.

Telethermography, which historically is derived from applications in the industrial and military fields, is performed using special infrared cameras that detect the skin temperature of the breast and transform it into a color image. Each color corresponds to a specific temperature range. Software processes these colors by finding thermal anomalies that help guide the diagnosis. It is also useful to compare the results between the two breasts and to study the thermal gradient.¹⁷⁴

The examination is performed using a liquid crystal plate (not with a camera as in thermography) that is placed on the breast. The liquid crystals change color based on the local temperature of breast tissue, creating an image that reproduces the circulation and temperature of the blood. In particular, the plate, showing a colored pattern, also provides information on thermal gradients. Considering a thermal gradient scale from 1 to 4, based on color intensity, gradient 1 corresponds to the absence of cancer and gradient 4 to the presence of cancer. To obtain a better representation of the colored image of the blood pattern, multiple plates with different temperature sensitivities are used. These technologies have been the subject of various scientific studies, with no unanimous conclusion. Looking at the scientific literature, many false positives and difficulty in interpretation due to the many variables that could have been present at the time of the examination are highlighted.

DATG is a technique that employs a thermographic instrument capable of recording temperature variations in breast vasculature

due to angiogenesis. The principle on which this methodology is based is that it is possible to obtain important information about the presence of cancer and precancerous lesions by studying vascularization.

DATG was developed as an evolution of contact thermography, still using liquid crystals but with an improved detector and in a different conception. The difference lies in identifying the heat due to vascularization of the mammary gland rather than the heat generated by cancer. The principle on which it is based is that cancer needs a strong blood supply to be born, develop, and grow (angiogenesis theory);¹⁷⁵ therefore, the acquired image will contain information related to altered vascularization in the presence of cancer. The basic idea is that every woman has her own thermographic image, which is like a fingerprint, and that any alteration of this image is evidence of suspected cancer or precancerous activity.¹⁷⁶

The machine used to perform this exam is composed of two parts: the mobile part consists of the thermographic sensor to be placed on the breast, and the second part is formed by the base connected to a computer that is responsible for recording the acquired images. The sensor is a liquid crystal plate, with improved sensitivity and spatial resolution, which records the distribution of blood at temperatures between 30°C and 35°C. When the sensor is placed on the breast, the heat due to vascularization excites the atoms of the crystal, causing them to change color. While in the previous contact thermography the physician studied the color, in the new DATG methodology the physician studies the shape of the image that is created. In a healthy breast, the formed image is due to normal vascularization, which appears as various signs that point towards the nipple. In the case of cancer or even a precancerous lesion, signs appear that have rounded shapes or converge from different areas of the breast to “nourish” cancer. So, the image interpretation is based on morphology. The standard procedure involves first examining the patient clinically (visit with palpation) and then acquiring two projections of the right breast (lateral and frontal) and two of the left one (lateral and frontal). Digital photos using infrared cameras are taken, and results are eventually compared with other thermographic photos acquired previously. In the case of visible superficial veins, the breast is cooled with a tool like a hairdryer.

The reference exams for breast cancer diagnosis are mammography and ultrasound, and in particular cases, MRI can also be useful. DATG is not an examination that replaces other tests, but rather it relates to them as a technique that adds additional useful information to clarify the clinical picture and improve the quality of the diagnosis.¹⁷⁷ DATG, with a quick (5–6 minutes per visit) and very precise execution, is a technique that does not require radiation or toxic drugs, can be used on patients of any age, has good specificity, and can diagnose even precancerous lesions, although it is not able to measure the size of the lesion, and is relatively inexpensive. Studies have been conducted that have shown how it is possible, through this methodology, to diagnose both infiltrating ductal carcinoma and infiltrating lobular carcinoma with the same accuracy,¹⁷⁸ even when mammography has difficulty identifying it.¹⁷⁹ Other possible applications include the monitoring of potentially dangerous breast therapies such as menopausal hormone replacement therapy and *in-vitro* fertilization.^{180,181}

On the other hand, DATG is not able to determine the size of the lesion, but rather it is a methodology that indicates the presence of a suspicious lesion and the area where to look for it. In fact, the intensity and size of the image acquired with DATG are correlated, not so much with the shape and size of the lesion but rather with its biological activity (angiogenesis theory). DATG examination does not use radiation, so it can be performed by both the radiologist

and the surgeon or oncologist, but anyone conducting the examination must be trained to recognize and interpret the images.^{182,183}

Biopsy imaging (guided biopsy techniques)

As we have said before, if imaging tests suggest the presence of a suspicious area, a biopsy may be required to confirm whether it is cancerous. Imaging guidance (such as ultrasound, mammography, or MRI) is used to help physicians accurately remove tissue samples for testing. The advantage of this technique is that it provides a definitive diagnosis by analyzing tissue samples. Its limitations are that it is invasive, it requires skill, and it involves some risk of complications like infection or bleeding.

PET and CT scanning

PET scans use radioactive glucose to identify cancer cells, which are often more active than normal cells. PET scans, combined with CT scans, are typically used to check whether cancer has spread beyond the breast to other parts of the body. This can be particularly helpful for staging cancer after diagnosis, particularly in patients with advanced disease. PET scans are not typically used for early detection but rather for assessing the spread of known cancer. They are expensive and have limited resolution in small cancers.^{184,185}

Molecular breast imaging

Molecular breast imaging is a newer emerging technique that uses small amounts of radioactive material to create images of the breast tissue and detect breast cancer cells. Early studies suggest that molecular breast imaging is effective in detecting small cancers when mammography and ultrasound are inconclusive. In fact, it is effective for detecting breast cancer in women with dense breast tissue. This technique has shown promise, but it is not yet widely available and is still under evaluation for routine clinical use.^{186,187}

Discussion

Early breast cancer screening typically begins at different ages depending on a person's risk factors, but for the general population, guidelines generally recommend the following: (1) for average-risk individuals, the American Cancer Society and other health organizations recommend starting mammograms at age 40 for women with average risk, with annual screenings for those aged 40–44 years, and biennial screenings starting at age 45. After age 55, individuals can continue biennial mammograms or switch to annual screening depending on personal preference and health; and (2) for higher risk individuals, if an individual has a higher-than-average risk (for example, a family history of breast cancer or inherited genetic mutations like BRCA1/BRCA2), screening may start earlier, typically around age 30 or earlier, and more advanced methods like MRI might also be included in the screening process.

The priorities and methods of screening can differ depending on age. The reason lies in both the biological changes over time and the individual's specific risk factors. For younger women (under 40 years), breast tissue tends to be denser, which can make mammograms less effective. For women under 40 years with higher risk factors, MRI is sometimes recommended as a complementary or primary screening method. Meanwhile, for middle-aged women (40–54 years), mammograms become more effective as women approach their 40s because breast tissue density begins to decrease.

Table 4. Comparison matrix for imaging modalities in breast cancer detection

Characteristic	Mammography	Ultrasound	Magnetic resonance imaging (MRI)	Positron emission tomography (PET)	Computed tomography (CT)
Purpose	Screening and diagnostic tool	Diagnostic tool, often after abnormal mammogram	Diagnostic tool for high-risk or dense breasts	Detection of metastasis and staging	Rarely used for breast cancer screening or detection
Strengths	Well-established in early detection, high sensitivity in dense breasts, good for calcification detection	Good for distinguishing cysts from solid masses, no radiation exposure, suitable for women with dense breast tissue	Excellent at detecting cancer in dense tissue, high sensitivity for detecting small cancers, useful for high-risk patients	Can detect metastasis, can provide information about cancer spread and staging	Provides anatomical detail, fast and widely available
Weaknesses	Lower sensitivity in dense breast tissue, can miss small cancers, radiation exposure	Limited ability to detect microcalcifications, operator-dependent, not useful for screening	Expensive, time-consuming, may require contrast agents, high false-positive rate	Not typically used for primary detection, limited resolution for small cancers, radiation exposure	High radiation exposure, less sensitive than MRI for detecting breast cancer, limited in assessing early-stage cancer
Detection sensitivity	80–90% (depends on breast density)	Moderate-to-high sensitivity for larger masses	90–95% (for invasive breast cancer)	Moderate for primary cancer, better for metastasis	60–80% (lower than MRI for breast cancer)
Screening utility	High (standard for breast cancer screening)	Low (only for diagnostic follow-up)	Low (not recommended for routine screening)	Very low (used mainly for metastasis detection)	Very low (used for staging or specific cases)
Radiation exposure	Yes (low dose)	No	No	Yes (high dose)	Yes (high dose)
Cost	Relatively low	Moderate to high	High	High	Moderate to high
Patient comfort	Moderate (compression)	High (noninvasive, no compression)	Moderate (involves a long scan and contrast injection)	Moderate (involves intravenous injection)	Moderate (requires patient to remain still)
Best for	Routine screening, especially in women over 40	Women with dense breasts or cysts, follow-up after abnormal mammogram	High-risk patients, dense breasts, unclear mammogram results	Evaluating metastasis and cancer staging	Staging and evaluation of extensive cancer spread

Most women in this age group are recommended to have annual or biennial mammograms, depending on their individual health risks. Older women (55+ years) can opt for biennial mammograms if their health is good, and screening is often less frequent unless new symptoms arise. For women with higher risks, such as those with a family history of breast cancer, screening may continue annually with additional tools like MRI or ultrasound as necessary.

Breast cancer screening guidelines often recommend that individuals be stratified according to their risk level, and the method of screening should differ accordingly. The breakdown is as follows: (1) For the low-risk population (average risk), mammography is the primary screening method and occurs biennially (every two years) or annually depending on the age and personal preference of women aged 40 years or older. (2) The moderate-to-high-risk population (increased risk) may have a family history of breast cancer, carry certain genetic mutations (like BRCA1 or BRCA2), or have other factors that place them at higher risk. The screening methods for the increased risk population include mammography, which is often used for most high-risk individuals, and MRI, which is used for individuals with very high risk, such as those with BRCA mutations or

a very strong family history. MRI is far more sensitive than mammograms for detecting cancer in dense breast tissue. In addition, ultrasound is sometimes used alongside mammography for women with dense breasts to get a clearer picture. (3) Those at very high risk may also benefit from genetic testing and counseling to determine other personalized screening options. These women may start screening earlier (often around age 30 or earlier, depending on the level of risk) and may undergo more frequent screenings (annually or more often) than the average population. For the very high-risk population (e.g., BRCA mutation carriers), MRI combined with mammography is often the gold standard screening method. Women with BRCA mutations or those who have had radiation to the chest area may begin screening as early as age 25 and do so annually.

The degree of risk plays a significant role in determining the starting age and methods of screening. While general guidelines recommend mammography for the average-risk population starting at age 40–45, higher-risk individuals often benefit from starting earlier, with the use of MRI, ultrasound, and other advanced screening methods based on their unique risk factors.

A matrix that compares key characteristics of different imaging

modalities for breast cancer detection would help to assess each technique's effectiveness in early breast cancer detection. Table 4 is a general structure for the comparison matrix, including key characteristics, strengths, and weaknesses of commonly used modalities.

Each imaging modality has its strengths and weaknesses, with different roles in breast cancer detection and management. Mammography remains the first-line screening tool for the general population, while ultrasound and MRI are often used for further investigation in specific cases. PET and CT are more relevant for cancer staging and metastasis detection rather than early detection. The choice of modality often depends on the patient's risk factors, breast tissue density, and the stage of cancer.

Like any other medical tool, imaging techniques have some gaps that can be summarized as follows: (1) limited accessibility and high costs—advanced imaging modalities like MRI and PET scans are expensive and not widely available, especially in low-resource settings; (2) radiation exposure risks—some imaging techniques, such as mammography and CT scans, expose patients to ionizing radiation, which may pose long-term risks; (3) false positives and overdiagnosis—many imaging methods detect benign abnormalities, leading to unnecessary biopsies and patient anxiety; (4) variability in sensitivity and specificity—no single imaging technique provides 100% accuracy, and sensitivity varies based on factors like breast density and tumor type; (5) integration of artificial intelligence (AI) and machine learning—although AI has shown promise in improving accuracy, its clinical application remains limited due to regulatory and validation challenges; and (6) lack of personalized screening approaches—current screening protocols do not fully account for individual risk factors, leading to under- or over-screening in certain populations.

On the other hand, technological advancements hold promising future directions in this field, such as (1) the development of low-cost imaging solutions—research into affordable, portable imaging devices can enhance early detection in underserved areas; (2) advancements in AI-powered diagnostics—improved machine learning models can assist radiologists in reducing false positives and improving diagnostic accuracy; (3) noninvasive biomarker integration—combining imaging with liquid biopsies and molecular markers may enhance early detection precision; (4) radiation-free imaging technologies—further exploration of thermography, optoacoustic imaging, and contrast-free MRI techniques can minimize radiation exposure; (5) personalized screening strategies—future research should focus on risk-adaptive screening protocols that tailor imaging methods based on individual genetic and lifestyle factors; (6) hybrid imaging techniques—combining modalities such as PET-MRI or ultrasound-elastography may provide more comprehensive breast cancer assessments; and (7) standardization of AI and imaging protocols—establishing global standards for AI-driven breast imaging interpretation will improve consistency and reliability in diagnosis. By addressing these gaps and advancing imaging technologies, breast cancer detection can become more accurate, accessible, and tailored to individual patient needs, ultimately improving survival rates and treatment outcomes.

Limitations

The applicability of each imaging approach discussed in this review may vary according to patient risk, breast density, lesion characteristics, and clinical setting. In addition, the diagnostic performance, accessibility, cost, and potential harms of different imaging methods are not uniform, which may affect their use in routine breast cancer screening and early detection.

Conclusions

Over time, it has become increasingly evident that we should draw our attention to the importance of prevention of cancer for women. In particular, the spotlight is on breast cancer and the essential periodic check-ups to identify, even at an early stage, cases that need monitoring or intervention. In fact, the latest generation of technologies and the expertise of dedicated specialist physicians allow for quick and increasingly precise answers.

Breast cancer is one of the most common diseases among women, and promptly identifying the symptoms is essential to ensure effective treatment, since early diagnosis can make a difference. However, not all cancers exhibit obvious symptoms. For this reason, imaging diagnostics, such as mammography, ultrasound, and MRI, are essential for an accurate evaluation.

Prevention through imaging diagnostics represents a fundamental weapon in the fight against breast cancer. Mammography, ultrasound, and MRI offer extra protection by detecting anomalies early. It is essential to regularly consult the healthcare provider and undergo check-ups, especially after the age of 40 or in the presence of suspicious symptoms. A regular check-up through imaging diagnostics helps detect breast cancer at an early stage, increasing the chances of successful treatment. If a woman notes changes in the breast, such as lumps or skin alterations, it is important to schedule a timely check-up. Early diagnosis can make a difference.

Acknowledgments

None.

Funding

No funding was received.

Conflict of interest

The authors have no conflict of interest related to this publication.

Author contributions

Study concept and design (CC), manuscript writing (CC, FB), critical revision (CC). Both authors have approved the final version and publication of the manuscript.

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