INTRODUCTION

The principle aim of breast imaging is to detect breast cancer. Breast cancer is a major health concern for women because of the great physical and emotional impact it has, not only on the afflicted person but also on her entourage. It is the most commonly diagnosed cancer in females with a one in seven lifetime probability of occurrence and the second leading cause of cancer death in women after lung cancer.

The 5-year survival rate ranges from 98% for early stage to 16% for advanced stage making detection in the sub-clinical phase crucial.

Mammography has been proven to detect cancer at an early stage and to reduce mortality especially with the substantial improvements in the quality of performance. However, this examination has a variable sensitivity that ranges between 60-90% and other adjunctive imaging modalities had to be introduced to contribute to the earlier detection of breast cancer mainly in young women and women at an increased risk.

FILM SCREEN MAMMOGRAPHY

Mammography is the primary modality for imaging the breast. It uses X-rays high in quality but low in radiation dose and it is either done to detect clinically occult cancer in asymptomatic women (screening mammography) or to evaluate breast abnormalities in symptomatic women (diagnostic mammography). Two standard views are usually obtained: a mediolateral oblique and a craniocaudal view (Fig. 1a, 1b).

Screening mammography is recognized as the most effective method for early detection of breast cancer. Several randomized trials have shown a substantial and significant reduction in breast cancer mortality in women over 50 years of age and in women aged 40 to 49 of about 40% [1-2].

A recent study undertaken by the Swedish Organized Service Screening Evaluation Group showed a reduction rate of the same order in tumors of size > 2 cm supporting further the reported mortality rates from breast cancer [3].

The American Cancer Society recommends screening mammography for women age 40 and above every year [4].

Once the examination has been done, it is not only important to check its quality but also to make sure that it will be adequately reported and understood. For this purpose, the American College of Radiology developed the Breast Imaging and Reporting System (BI-RADS) as a standard method of reporting mammograms.

The BI-RADS report states the composition of the
breast in terms of relative amount of fatty and dense tissue which affects the sensitivity of mammography.

There are four types:
1. The breast is almost entirely fatty (Fig. 2).
2. There are scattered islands of fibroglandular tissue.
3. The breast tissue is heterogeneously dense.
4. The breast tissue is extremely dense (Fig. 3).

The report also describes the mammographic findings using a standardized lexicon for masses and calcifications. This system will provide a final assessment with a management recommendation and include six categories [5].

- CATEGORY 0: Need additional imaging workup.
- CATEGORY 1: Negative.
- CATEGORY 2: Benign findings (Fig. 4).
- CATEGORY 3: Probably benign findings: < 2% chance of malignancy, short interval follow-up is needed (Fig. 5).
- CATEGORY 4: Suspicious: Intermediate probability of cancer 3-94%. Biopsy should be considered. This category has been further subdivided into 4A, 4B and 4C according to a low, intermediate and moderate suspicion level for cancer.
- CATEGORY 5: Highly suggestive of malignancy
with a > 95% risk. Biopsy is strongly recommended (Fig. 6).

- **CATEGORY 6:** Known biopsy proven malignancy.

- **Mammography in special circumstances:**

  a. In young women: Women in their 20s and 30s with no risk factors should have a clinical breast exam by a health professional every three years as recommended by the American Cancer Society.

  Young females at high risk of developing breast cancer due to BRCA1 or BRCA2 gene mutation or strong family history should have a mammogram on yearly basis.

  b. In the surgically treated breast: Nowadays most of the breast cancers are treated by breast-conserving treatment without removing the entire breast. These women should continue to have bilateral mammography.

  When a mastectomy has been performed with or without reconstruction, no further routine mammogram of the affected side is needed.

  For breast enlargement: Women with implants will have four additional (implant displacement) views along with the four standard views (Fig. 7). Other imaging modalities may be needed for assessing the implant.

  Conventional two views mammography does not reveal all cancers. Its sensitivity ranges from 63-98% and can be as low as 30-40% in dense breasts [6]. New technologies have been developed to improve on breast cancer detection such as:

  1. **Full-Field Digital Mammography**

     It also uses X-ray but the images are captured electronically and viewed on a computer screen. It allows a faster acquisition with shorter exposure time. Although the cost is more than standard mammography, images can be modified with no additional views and need for a recall visit. This technique has a similar overall diagnostic accuracy as film mammography but is more sensitive in women younger than 50 years, pre- or perimenopausal women, and women with radiographically dense breasts as shown by digital mammographic imaging screening trial (DMIST) conducted by the National Cancer Institute [7].

  2. **Computer-aided Detection and Diagnosis (CAD)**

     It is intended to help radiologists identify suspicious lesions that may otherwise be overlooked. It acts as a second set of “eyes”. The image whether film screen or digital is analyzed by a computer which will mark masses or microcalcifications. The use of CAD has not significantly changed the overall breast cancer detection rates. This technique is meant to assist the radiologist but should not alter his decision [8].

  3. **Digital Breast Tomosynthesis**

     It utilizes conventional mammographic X-rays tubes. Digital detectors swing over the breast in an arc producing multiples images which are then reconstructed into a 3D series of thin high resolution slices. Lesions become more visible because tomosynthesis eliminates superimposition of normal breast structure, an important impact factor on cancer detection especially in dense breasts. The radiation dose is comparable to conventional mammography [9].

     Despite these advances, mammography continues to have limitations when used in isolation. Its positive predictive value can be as low as 10% demonstrating the need for other imaging modalities.

- **ULTRASONOGRAPHY**

     It is a non invasive, widely available imaging modality that uses high frequency sound waves to image the breast. It is performed by radiologist trained in breast imaging because it is highly operator dependent. Traditionally, it was performed to differentiate cysts from solid masses (Fig. 8). Recent and ongoing techno-

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**FIGURE 6.** BIRADS 5: Spiculated lesion representing carcinoma.

**FIGURE 7.** Bilateral retroglandular saline implants: standard view and view with implant displacement.
logical developments allowed it to acquire a major role in detection and diagnosis of breast diseases.

The American College of Radiology has set practice guidelines for the performance of a breast ultrasound examination [4]. Breast sonography should be used for:

1. Identification and characterization of palpable and non-palpable abnormalities and further evaluation of clinical and mammographic findings (Fig. 9a, 9b).
2. Guidance for interventional procedures (Fig. 10).
3. Evaluation of problems associated with breast implants (Fig. 11).
4. Treatment planning for radiation therapy.

**Figure 8.** Well defined opacity on mammography better characterized by sonography: cyst (*) and fibroadenoma (arrow).

**Figure 9.** Normal mammogram of a dense breast (a) and incidental small carcinoma on sonography (b).
Other potential indications include evaluation of palpable masses in women less than 30 years of age and in lactating and pregnant women.

The American College of Radiology has also established a framework of feature categories for analyzing breast lesions, the BI-RADS, which includes six categories like that of mammography [5].

Ultrasound (US) is a valuable adjunct to mammography but what is its current status as a screening tool? Early studies on potential use of US for breast cancer detection were first evaluated in 1980 [10]. Ultrasound was not useful as a screening test because of inadequate detection of small cancers and excessive false positive biopsy rate. It is more time consuming and more expensive.

Since 1995, US screening for breast cancer has been reevaluated in six series totaling 42838 examinations with high resolution transducers. Study populations were heavily weighted towards women with higher density breast [11]. The results show that screening US has been able to depict substantial number of early invasive cancers that were not identified by mammography in women with dense breast. Ultrasound can detect 10-40% of mammographically occult cancers depending on patient’s breast density and age and it is useful for detection of multifocal cancer.

However, there are many valid reasons why these studies do not yet justify a recommendation for US screening of general population or even women with dense breasts; the readings were not blinded or independent to mammographic findings and the interpretive and technical quality of both modalities should be optimized and documented.

A multicenter US screening study sponsored by Avon & the ACR Imaging Network (ACRIN) funded by the National Cancer Institute is undertaken taking into account the latter weak points. The purpose of the ACRIN protocol 6666 is to determine whether and how frequently whole breast bilateral US screening can depict cancers that are not visualized at mammography. Asymptomatic women with dense breast will be screened annually for three successive years by mammography and US at 20 different centers. The trial will separately evaluate the relative performance of US and both prevalence and

**FIGURE 10.** Ultrasound-guided biopsy.

**FIGURE 11.** Breast implants rupture: (a) Mammography (b) Ultrasound showing snow storm and silicone cyst appearance from extracapsular silicone leak (arrow).
incidence screening. Enrollment is limited to very high risk patients [12].

Although not yet accepted as a screening modality, sonography remains an indispensable tool in breast imaging armamentarium.

Most benign and malignant lesions can be accurately categorized as a result of improvements in gray scale imaging and development of sensitive color Doppler as well as vascular mapping, US contrast agents, harmonic imaging and elasticity imaging. Ultrasound elastography is a promising technique for evaluating breast lesions with a higher specificity and accuracy when compared to sonography. The combination of these two techniques offers the best results in detecting cancer and potentially may reduce unnecessary biopsy [13].

MAGNETIC RESONANCE IMAGING

It utilizes magnetic fields to produce cross-sectional images of the body with a very good soft tissue contrast resolution. In breast imaging, the administration of intravenous paramagnetic contrast material is crucial allowing for better detection of cancer. A dedicated breast coil is required. MRI has a high sensitivity in detecting breast cancer ranging between 94-100% but its high cost and low specificity may increase the rate of unnecessary biopsies, making it an unacceptable screening tool for the general population [14].

The currently accepted diagnostic and screening applications of breast MRI are [15]:

1. Local staging of cancer
2. Evaluation of response and residual disease after neoadjuvant chemotherapy
3. Evaluation of post-lumpectomy bed: scar versus recurrence
4. Assessment of positive margins post lumpectomy
5. Evaluation of chest wall invasion before surgery
6. Assessment for an occult primary with positive axillary adenopathy
7. Problem solving tool in inconclusive mammographic, sonographic and clinical findings
8. Diagnosis of breast cancer and evaluation of implant integrity
9. Assessment of contralateral breast disease. MRI can detect clinically and mammographically occult cancer in the contralateral breast with a negative predictive value of 99% allowing simultaneous treatment of synchronous cancers when present and avoiding unnecessary prophylactic mastectomy [16].
10. Surveillance of high risk patients: only after genetic counseling. In this regard, the American Cancer Society has published guidelines for breast screening with MRI as an adjunct to mammography [17].
11. Women at high risk (greater than 20% lifetime risk, this group includes women with a strong family history of breast or ovarian cancer and women treated for Hodgkin’s disease) should get an MRI and a mammogram every year. Women at moderately increased risk (15% to 20% lifetime risk) should talk with their doctors about the benefits and limitations of adding MRI screening to their yearly mammogram. Yearly MRI screening is not recommended for women whose lifetime risk of breast cancer is less than 15%.

Despite its high cost, MRI has been increasingly used. However, the quality of the exams, the accurate reporting using the BI-RADS MRI lexicon as well as the availability of MR guided biopsy in the centers where MRI is performed are crucial for best results achieved by this imaging modality.

NUCLEAR MEDICINE

Nuclear medicine studies involve the injection of radioactive substances into the body and provide functional information on the pathophysiology of both normal tissues and disease. In general screening for breast cancer, there seems to be no role for nuclear medicine. Scintimammography, however, seems to have a role as a second line test in patients with nonconclusive ultrasound and mammography results. In this group of patients, scintimammography detected 20% additional cancers [19]. This modality appears to be superior to ultrasound and mammography for lesions above 7 mm. Below this size threshold it may not have any advantage over MRI.

Positron emission tomography (FDG-PET) detects breast masses especially when palpable and larger than 8 mm in diameter. It lacks however specificity and there is overlap among benign and malignant lesions. It is therefore reserved for tumor staging. It can detect both the primary tumor and the metastatic deposits whether nodal, visceral or skeletal in one single procedure exploring the whole body [20].

Radionuclide Lesion Localization (ROLL)

10 MBq of 99mTc MAA are injected into the tissue adjacent to the suspected lesion. The radiotracer is identified intraoperatively by a probe and the tumor is totally excised.

Sentinel Nodes

Sentinel lymph node mapping is an increasingly utilized technique in the preoperative planning of women with small (< 25 mm) lesions and no documented axillary metastasis. 10MBq of colloid particles (0.1-0.4 mm) are injected in the subdermis above the tumor. Imaging is performed preferably with the patient in the position she will be at during surgery. Radioactivity is identified intraoperatively by a hand held probe and node can also be visualized after blue dye injection before surgery. Using these techniques the success rate of sentinel node detection may be as high as 98% [21].

Bone Scintigraphy

A very sensitive and simple test to evaluate bone metastasis. It relies on increased metabolic turnover that
occurs around metastatic bone lesions. The examination is however nonspecific and uptake may be seen at sites of degenerative disease. When to do bone scintigraphy remains a debate with some authors recommending it for patients with large tumors (T3 and T4) and those with bone pain or axillary disease irrespective of symptoms. Others do it as part of evaluation of all patients [22].

**IMAGING-GUIDED BREAST BIOPSY**

Regardless of the method of detection, the presence of cancer can only be confirmed by a biopsy. Traditionally, diagnosis was made postoperatively after excisional biopsy with or without wire localization. The latter is used in cases of non-palpable lesions and microcalcifications (Fig. 12). Nowadays, the diagnosis should be made preoperatively and this has been made available through the advent of needle biopsy. This can be done under ultrasound guidance i.e. the fine needle aspiration (FNA) and core biopsies, or under stereotactic guidance i.e. the vacuum-assisted biopsy which is used for microcalcifications. Having a lower sensitivity (52-95%) and specificity (95-100%) than the other techniques, FNA is usually reserved for cyst aspiration or axillary lymph node sampling.

The knowledge of the diagnosis before the surgery is very important. It will allow the surgeon to plan his surgery achieving a more complete excision and decreasing the rate of positive margins [15].

**CONCLUSION**

Mammography is currently the only imaging modality for breast cancer screening. However it cannot be used in isolation for complete evaluation.

Ultrasonography is used for better characterization of masses, detection of additional lesions mainly in dense breasts. It is also useful for assessment of the axilla and for biopsy guidance. Routine screening with ultrasound is not currently recommended.

Magnetic resonance imaging is a powerful tool in breast cancer detection. It has 100% specificity for invasive malignancies and recently has been advocated as an adjunct to mammography for screening of high risk women.

However, in order to achieve the optimal care, the approach in breast cancer should be multidisciplinary involving the clinician, the radiologists, the surgeon and the oncologist and going through the assessment process which comprises clinical examination, imaging for detection, biopsy for tissue diagnosis and staging.

**REFERENCES**