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REVIEW

Misdiagnosis in breast imaging: a statement paper from European Society Breast Imaging (EUSOBI)—Part 2: Main causes of errors in breast imaging and recommendations from European Society of Breast Imaging to limit misdiagnosis

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Abstract

Importance Breast cancer is one of the leading causes of negligence claims in radiology. The objective of this document is to describe the specific main causes of errors in breast imaging and provide European Society of Breast Imaging (EUSOBI) recommendations to try to minimize these.

Observations Technical failures represent 17% of all mammographic diagnostic negligence claims. Mammography quality control protocol and dedicated training for technologists and radiologists are essential. Lack of consideration of the clinical context is a second critical issue, as a clinical abnormality is found in 80% of malpractice claims. EUSOBI emphasizes the importance of communication and clinical examination before the diagnostic investigation. Detection errors or misapplications of the lexicon or Breast Imaging Reporting Data System (BI-RADS) score account for 5% of malpractice claims and should be reduced by limiting radiologists' distraction or fatigue, and being aware of satisfaction of search errors and the importance of a personal systematic review. Errors related to pathological concordance and MDT review can be limited by the use of markers after biopsy and the use of standardized reports, which can aid communication with other specialities. Finally, errors related to tumor or patient factors should be discussed, considering the use of contrast-enhanced mammography and magnetic resonance imaging.

Conclusion Several factors are responsible for misdiagnosis in breast cancer, including errors in the practice of the technician and/or radiologist (technical failures, lack of consideration of the clinical context, incorrect application of the BI-RADS score, false reassurances), lack of communication with other specialists or with the patient, and the type of tumor and breast parenchyma.

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Key Points

Question *What factors most contribute to and what implications stem from misdiagnosis in breast imaging?*

Findings *Ongoing training and education for radiologists and other healthcare providers, as well as interdisciplinary collaboration and communication is paramount.*

Clinical relevance *Misdiagnosis in breast imaging can have significant implications for patients, healthcare providers, and the entire healthcare system.*

Keywords Misdiagnosis, Breast cancer, Mammography, MRI, Ultrasonography

Introduction

Misdiagnosis in breast imaging has strong implications for both patients and radiologists, as detailed in the first part of this statement paper (Paper Part 1). To limit the number of misdiagnoses, the radiologist must know the main causes that can contribute to missing a breast cancer.

According to the classification of common radiological errors presented in Paper Part 1, the specific causes of errors in breast imaging include (1) When first readers missed the specific abnormality that caused the error: Detection errors either due to technical failures (pre-reporting errors, which include all acquisition mistakes that may cause the reader to miss the specific abnormality) or due to perceptual errors (reporting errors, which are lesions missed by the first reader and detected by an expert); (2) When the first readers identified the abnormality but misinterpreted, the error is considered as Interpretive (cognitive) errors including errors of assessment (reporting errors) or errors of management (post-reporting errors); (3) When no reason was clearly identified, the radiologist recorded whether the lesion had any atypical features or is not detected due to the background [1]. Moreover, an additional type of error, which is particularly significant in breast imaging, is the inappropriate choice of imaging modality (i.e., errors of indication), which can vary depending on the clinical context.

Thus, in the second part regarding misdiagnosis in breast cancer, we will present the specific causes of errors in breast radiology and propose European Society of Breast Imaging (EUSOBI) recommendations to limit the number of misdiagnoses.

Detection errors (technical failures and perceptual errors)

Technical failures are identified as being responsible for missed breast cancer in 17% of diagnostic mammography malpractice claims [2]. In 20% of diagnostic cases in which diagnostic errors were reported, image quality was cited as a problem [2]. According to a recent assessment of practices in Canada, half of the technicians who perform mammography exams failed audits in a substantial percentage of their mammography exams that demonstrating critical failures in breast positioning [3]. In fact, the main sources of technical errors identified were due to positioning where not all of the breast tissue is included, poor tissue compression (Fig. 1), inadequate exposure factors during image acquisition and misuse of protocols (Table 1). Secondly, the errors may be missed by the first reader but detected by an expert (perceptual errors). This phenomenon is mainly observed in the case of subtle findings (for example, a cluster of amorphous calcifications, architectural distortion) or poor lesion conspicuity (non-mass forming tumors).

Fortunately, most European countries have organized double reading of screening mammography [4] that limits but not erases this type of perception error [5–8]. One of the main quality assurance roles of the expert radiologists in European breast screening programs is to identify poor positioning which is an important quality criterion in mammography (Fig. 2).

Within the last few years, five studies have compared single versus double reading using digital mammography (DM) [9–13], four retrospective and one prospective. In each of the studies cancer detection rate was higher for double (5.2–8.8 per 1000 screens) than single reading (4.8–8.0 per 1000 screens). Importantly interval cancers were also shown to be less common with double reading (0.6–3.0 per 1000 screens) than single reading (0.9–6.1 per 1000 screens). There is no convincing evidence that breast density alters the benefit of double reading [10]. Finally, a negative conventional imaging test does not completely rule out the possibility of underlying cancer. Double reading helps but is not able to prevent all errors. Failure to continue the investigation with second-level imaging techniques, such as contrast-enhanced imaging (CE-imaging) and magnetic resonance imaging (MRI), can lead to so-called interval tumors. Interval cancers are tumors diagnosed after a negative screening episode and before the next screening invitation. They can be classified into true interval cancers, false negatives, minimal-sign cancers, and occult tumors based on mammographic findings in screening and diagnostic mammograms. Almost half of the interval cancers are true interval cancers, including a high percentage of tumors with poor prognosis tumors related to molecular profile [4].

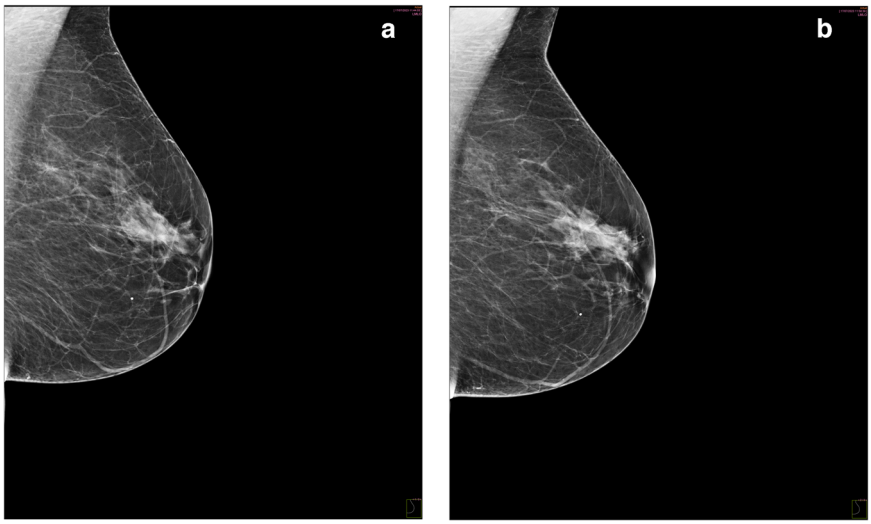

Fig. 1 Effect of insufficient compression. The presence of an asymmetry that disappears after correct positioning of the patient and good compression (> 120 N MLO/ > 100 N CC). **a** Insufficient compression. **b** Correct compression

Interval cancers are particularly observed in women with extremely dense breasts due to the masking effect in mammography and the inherent higher risk of breast cancer. A recent study demonstrated the impact of MR imaging screening in this cohort with a significant reduction in interval cancer in women screened with MRI compared to mammography alone [5]. False-negative and occult tumors have similar phenotypic characteristics to screen-detected cancers, with high breast density being strongly associated with occult tumors [6]. Minimal-sign cancers are biologically close to true interval cancers but show no association with breast density [4]. Knowledge of the clinical and biological characteristics of interval cancers and the role of breast density may be useful for the design of new risk-based screening strategies [7, 8]. Different personalized strategies are currently being investigated, including the WISDOM study in the USA [14] and MY PEBS in Europe [15].

The EUSOBI quality control recommendations are presented in Table 1 and summarize most of the recommendations for limiting technical errors in mammography (Figs. 3–5).

Interpretative errors

Errors in assessment and management are considered interpretive (cognitive) errors. In the UK national screening program, this is around 5–10% of all errors [16]. Before analyzing the causes of interpretive/cognitive errors, it is important to understand the process of human decision-making. Large analyses have found two main types of decision-making: type 1 (also known as heuristics), which is unconscious, intuitive, and faster, and type 2, which is systematic, analytic, effort-consuming, and time-consuming [17]. Most cognitive errors in breast imaging are related to type 1 decision-making processes [18]. The conscious effort of applying type 2 decision-making could already be useful in preventing misinterpretation errors. A second parameter that should be taken into consideration is the proper training of breast radiologists with special emphasis on technical issues, patient characteristics, and benign-looking or slowly growing lesions with a sufficient volume of cancer cases during the training period. A Dutch study compared missed breast cancer at repeated recalls at screening mammography between women tested with screen-film versus DM and reached some interesting conclusions [2]. Firstly, most delays were caused by incorrect Breast Imaging Reporting Data System (BI-RADS) classifications and false-negative results at biopsies. Secondly, ductal invasive cancers were more frequently delayed than ductal carcinoma in situ. Finally, the delayed confirmation of breast cancer significantly increased the mean tumor size. Despite notable improvements in breast imaging technology, the delays were similar between teaching and non-teaching hospitals. This phenomenon underlines the necessity of collaboration between teaching and non-teaching hospitals, with radiologists working in both centers and periodic meetings to discuss about complex cases.

Importance of consideration of clinical context or false reassurance

Self-examination is no longer advised in some countries for patients as it leads to too many false-positive palpation

Table 1 EUSOBI quality control recommendations

Mammography/digital breast tomosynthesis/contrast-enhanced mammography	
Positioning (Fig. 6)	MLO view: (1) Visibility of retroglandular clear space ("Milky Way") (2) Visualization of the pectoralis muscle to the level of the nipple (3) breast tissue that is well positioned in an up-and-out orientation (4) open inframammary fold (5) difference of posterior nipple line measurement between CC and MLO < 1 cm.
	CC view: (1) Visibility of retroglandular clear space ("no-man's-land") (2) Nipple centered and out of the breast (3) Difference of posterior nipple line measurement between CC and MLO < 1 cm) Visibility of the pectoralis muscle (30%) or at least complete visualization of posterior breast tissue
Compression	CC view: compression strength > 100 N
	MLO view: compression strength > 120 N
	Low difference of compressed breast thickness (< 1 cm)
Protocol misuse	Cluster of microcalcifications: magnification on CC and medio lateral view (90 degrees)
	Mass: DBT or Spot view (If DBT is available, DBT should be preferred regarding its lower radiation dose). No magnification to analyze the margin except if the mass is located in fatty tissue
Ultrasonography (Fig. 7)	
Focal zone	At the level of the lesion
Measurements	Two perpendicular plans of each lesion
	If multiple lesions, the distance between lesions and external extreme distance
Location	Side, quadrant, clock hour, and distance to the nipple
	Always correlate with MG and/or clinical abnormality
MRI	
Positioning and quality	No folds
	Homogeneous fat suppression on the mask
	First and last slice outside of both breasts
	Phase coded in a transversal plan
	Nipple facing 12 h
Time	If possible second week of the menstrual cycle (D7–D14)
Injection	Absence of contrast in the heart on the mask
	Presence of contrast in the heart on native IV + images
Percutaneous biopsy (Fig. 8)	
Location	Side, quadrant, clock hour, distance to the nipple and mammary zone
Type of needle	Core needle biopsy is recommended for masses
	Vacuum-assisted biopsy is recommended for non-mass (MG, US, MR)
Post-biopsy marker	Lesion < 5 mm
	Cystic lesion with papillary nodule, intraductal lesion
	Targeted US after MRI
Report	
BI-RADS 0	Must not be definitive and should be modified after complementary examination by the radiologist
BI-RADS 3	Must be recalled by the radiologist as well as the clinician
BI-RADS 4 or 5	Must be recalled for a percutaneous biopsy by the radiologist

results as well as false reassurance (false-negative palpation results) [19]. However, clinical examination by the medical staff who have more experience in palpation is included in the protocol of screening (beside mammography) in some countries.

Clinical breast examination conducted every two years by primary health workers significantly down-staged breast cancer at diagnosis and led to a significant reduction of nearly 30% in mortality in women aged ≥ 50 years old in comparison with no screening [20]. In addition, Kopans et al reported that 5–15% of palpable breast cancers are not detected on mammograms [21]. Lesions out of field of view on mammography are usually palpable (usually because they are more superficial (for instance, within the inframammary fold), hence the importance of considering patients' concerns about palpable abnormalities and dismissing too quickly after a negative mammogram (Figs. 6 and 7) [22]. In case of recurrence of breast cancer, 60% of patients are symptomatic and report a change [23]. This underlines the importance of

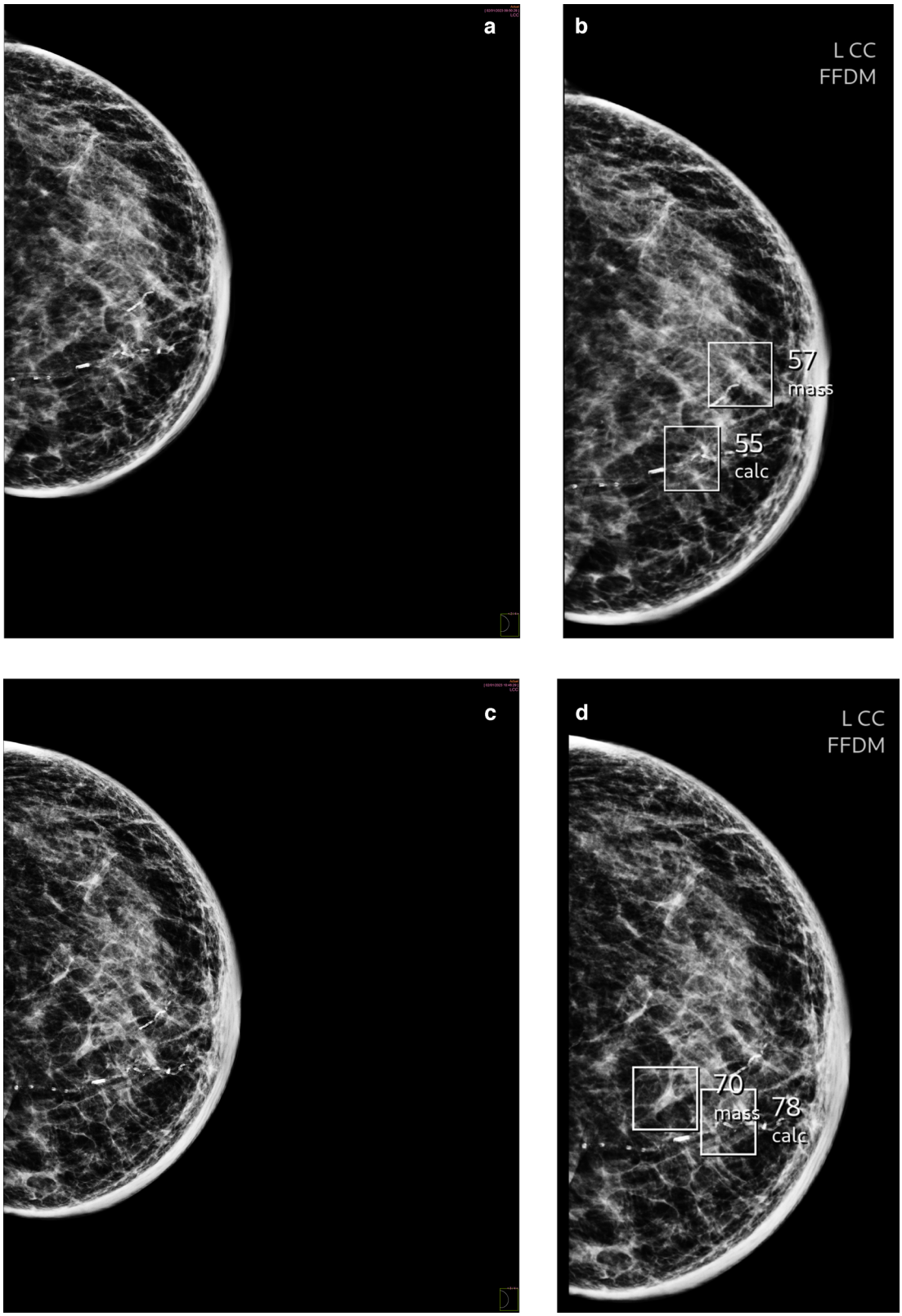
a
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Fig. 2 Effect of kinetic movement on the evaluation by AI of a cluster of microcalcification. In case of poor technique, there is an underestimation of the suspicion of malignancy on a mass that was finally a radial scar. These cases demonstrate, in addition, the limitation of AI for false-positive vascular calcifications. **a** Poor technique CC MG with kinetic artifacts. **b** Results of AI software on a poor technique CMG with kinetic artifacts. **c** Good technique CC MG in the same patient. **d** Results of AI Software on good technique CC MG

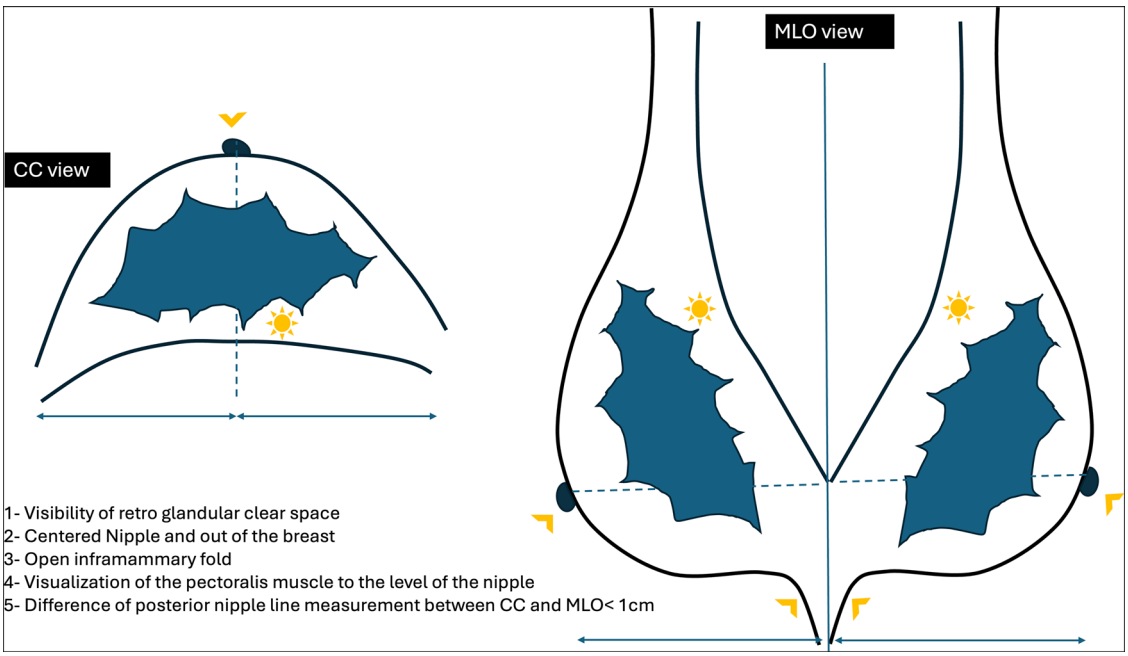

Fig. 3 Quality criteria for MG positioning. Five quality criteria exist that need to be checked on CC and MLO views to evaluate positionning : (1) visibility if retroglandular clear space (star), (2) Centered Nipple and out of the breast (head arrow), (3) Open inframammary fold (head arrow) (4) Visualization of the pectoralis muscle to the level of the nipple (dotted line with arrows) (5) Difference of posterior nipple line measurement between CC and MLO < 1 cm (continuous line with arrows)

developing good communication with the patient. The radiologist should take into consideration the clinical history and should carefully listen when a patient explains that something has changed.

Errors due to misapplication of BI-RADS lexicon and scoring system

Breast imaging comprises several modalities, such as MG or DBT, US, MRI, contrast-enhanced mammography (CEM). When a lesion is depicted on one modality and needs to be verified on another for diagnostic and/or biopsy purposes (usually between mammography and ultrasound or MRI and ultrasound), correlation between modalities is of paramount importance in order to prevent interpretive errors.

Nowadays, the use of DBT provides a good reference on the site of the lesion and adequately guides a targeted diagnostic ultrasound. When only MG is available, triangulation is necessary before performing US. This concept of triangulation is extremely important in identifying the actual position of a lesion. It implies the projection of a true or theoretical mediolateral view by drawing a line through the lesion on both the mediolateral oblique and cranio-caudal view. In the case of mediolateral oblique (MLO)-only lesions, a medial lesion will move superiorly on the lateral view, whereas a lateral lesion will move inferiorly. A lesion seen posteriorly high near the pectoralis muscle on MLO view might be in the upper outer quadrant, near the axilla, but can also be located in the upper inner quadrant. Exaggerated craniocaudal views may be helpful in demonstrating a posteriorly located lesion that is seen on the mediolateral oblique view only.

Attention should be given when performing diagnostic US to search for lesions not only on the axis indicated by triangulation (usually using the clock-face configuration as indicated on BI-RADS Lexicon) but also at the same distance from the nipple. Falsely reassuring negative US is one of the most common interpretation errors [24, 25], hence the importance of correctly applying triangulation. This is a frequent reason for false reassurance; i.e., MG lesions are not correctly "triangulated" and, as such, searched on the wrong axis on the US and falsely considered as negative [24].

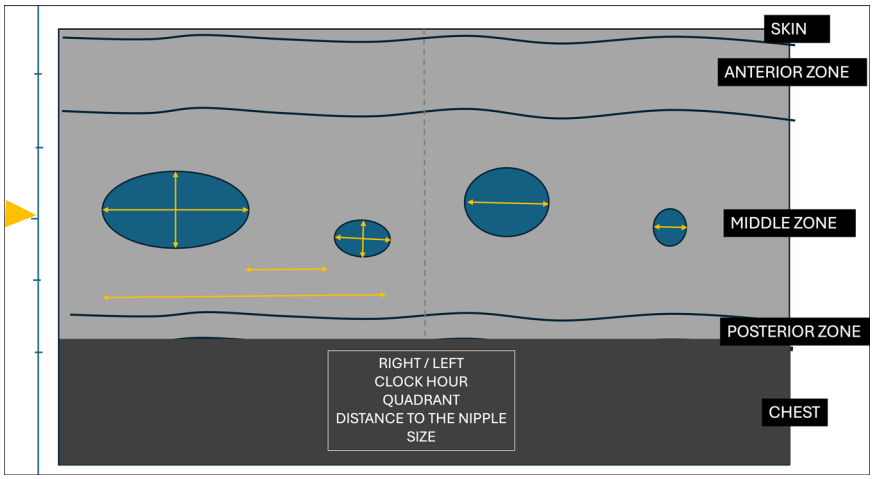

Fig. 4 Quality criteria for US description of a mass. The arrow corresponds to the position of the focal point. The position of any lesion detected by ultrasonography should be detailed as follows: side, clock hour, quadrant, and distance to the nipple. For size, the different measurements need to be given: 3 axes (two orthogonal in longitudinal views (left part of the picture) and one in axial view (right part of the picture). When masses are multiple, intralesional and extreme external distances should also be precise

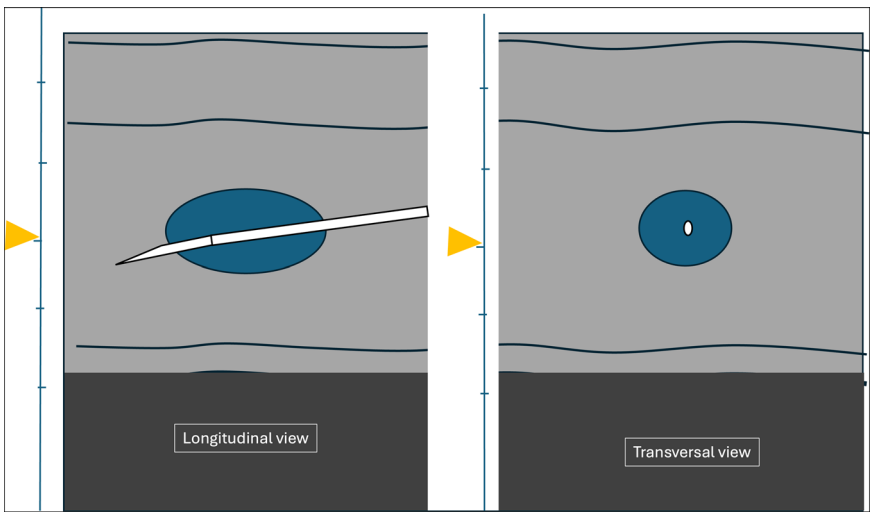

Fig. 5 Post-biopsy US image to ensure the visibility of good targeting. Two views should be performed in two orthogonal plans: one longitudinal showing the needle crossing the target and one transversal where the needle is visible as an echoic point which must be located inside the target

In case of second-look post-MRI ultrasound, similar rules apply. Axis and distance from the nipple should be concordant, and changes in patient positioning should be considered. Searching for subtle or isoechoic lesions may require specific ultrasound techniques such as harmonic imaging, elastography, or power doppler (Table 1).

A negative US finding at the site of a suspicious lesion should not preclude biopsy. If a sonographic correlate is seen and US-guided biopsy is performed, a post-biopsy marker should be placed particularly if the lesion is smaller than 5 mm and a post-biopsy mammogram should be obtained to confirm the mammographic-sonographic correlation [26].

Another source of common error is misuse of the BI-RADS 3 category, with especially misapplication of BI-RADS in the evaluation of margins, which is the most informative feature to distinguish benign from malignant tumors. At mammography, the analysis must be conducted on dedicated views such as spot view or breast tomosynthesis. In ultrasonography (US), the most common mistake is suboptimal use of technical parameters such as the focal point at the level of lesion of interest [27, 28]. Using MRI, the analysis needs to be performed both on subtracted images and on native images (speculation may be missed on subtractions, whereas pre-contrast high signal in lesions may obscure enhancement

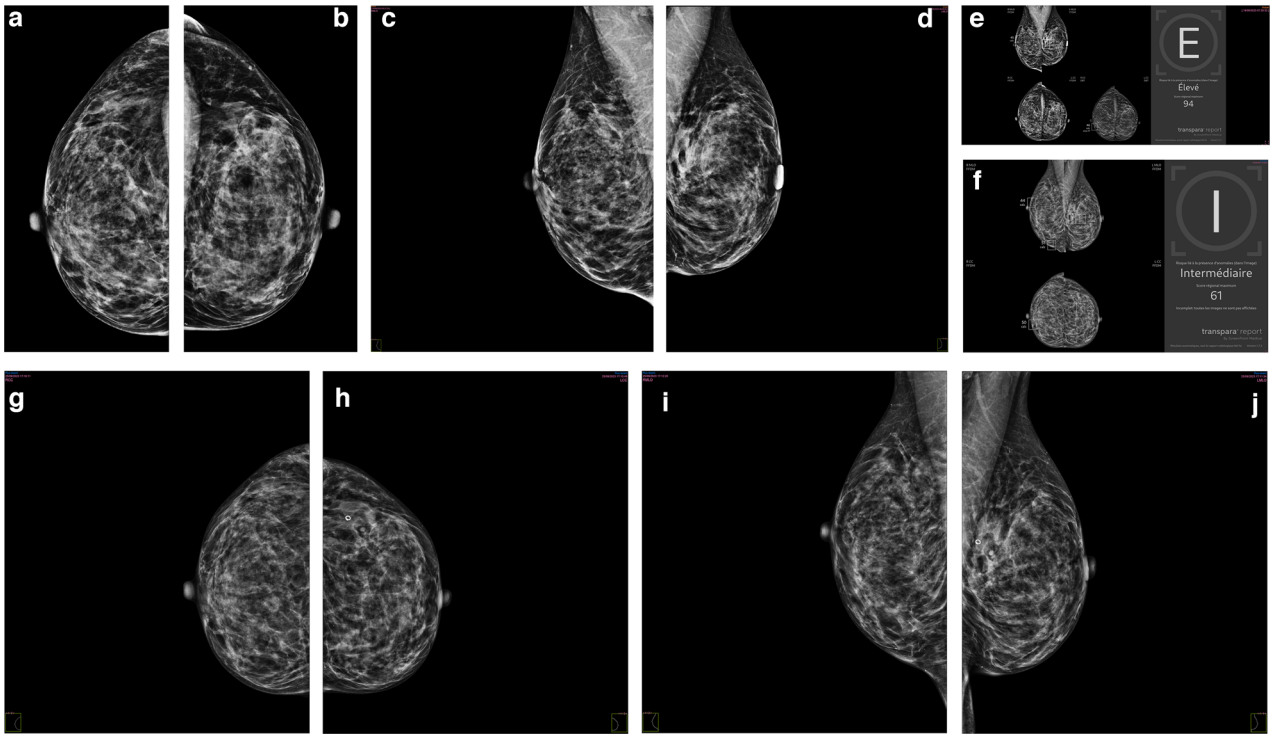

Fig. 6 Palpable left breast cancer with the results of AI system in two different mammograms performed at one week of interval. The cancer is not easy to detect, especially with the second manufacturer, and was not detected by AI on DBT on the first system and on MG on the second system. First mammogram (**a**–**d**). Results of AI softwere on the first mammogram (**e**). One week later mammogram (**f**–**i**). Results of AI software on the one week later mammogram (**j**)

in native images). Moreover, assessment of both early and late images may help to depict a possible blooming sign (margins becoming unsharp in the late phase, suggestive of malignancy) [29]. Thus, a complete diagnostic evaluation should be performed before characterizing a lesion as BI-RADS 3 [30]. Furthermore, an appropriate follow-up should be performed and histopathologic confirmation should be obtained for significantly enlarging circumscribed masses (20% size increase within a 6-month interval) [30].

Errors due to pathology-related and team decision-related issues

When encountering a finding that does not strictly meet the criteria for a benign or probably benign lesion (lesions rated BI-RADS 4), histopathologic confirmation should be obtained. It is essential to proceed with thoughtful radiologic-pathologic correlation after biopsy and to repeat the biopsy, either surgically or percutaneously, for discordant lesions, when the histologic findings do not provide an acceptable explanation for the imaging features [31]. The false-negative rates for US-guided and stereotactic vacuum-assisted core-needle biopsies have been estimated to be 4% and 1.1%, respectively [32]. For benign concordant lesions, consideration should be given to establishing an imaging follow-up protocol to monitor interval changes and identify delayed false-negative diagnoses, particularly in women who do not undergo screening.

A frequent factor of misdiagnosis is communication failure with the patient and/or other specialities [32]. Multiple hospital departments and sometimes outsourced outpatient clinics (radiology, MRI, pathology, etc.) can be involved in the diagnostics of the same patient, therefore very precise data transfer is unconditional. Standardized reporting features such as BI-RADS are helpful, but more detailed coordination is frequently needed. It is of utmost important that the radiologist evaluates the concordance of imaging and biopsy (pathology) results.

A good example is not documenting the absence of small calcifications in the pathology report after a stereotactic biopsy. This discordance may not be revealed by the other clinicians (oncologist, surgeon, GP) and could lead to false reassurance of the patient and a delay in diagnosis.

Concordance could also be “partial, (e.g., relevant or just a minimal-size histological lesion—as atypical ductal hyperplasia or lobular carcinoma in situ—in a

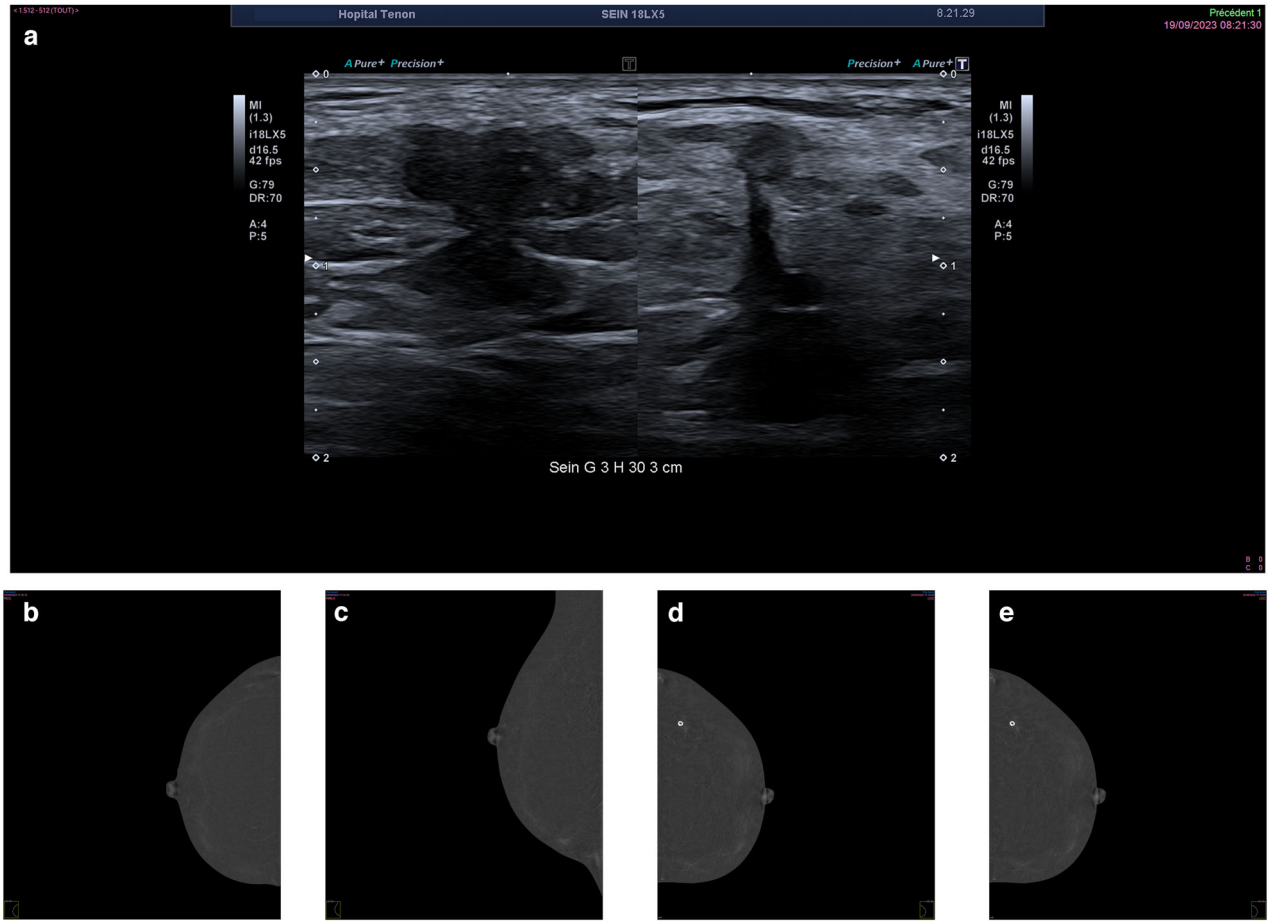

Fig. 7 This cancer was difficult to diagnose on imaging (both MG and CEM mammo) but easily detected by clinical examination and ultrasonography. **a** Ultrasonography. **b**, **c**, **d**, **e** Contrast-enhanced mammography (RCC, LCC, RMLO, LMLO views)

vacuum-assisted biopsy, behind a large imaging abnormality). Situations could have an impact on the further management of the lesion.

This could be supported by a weekly meeting with a radio-pathological correlation of all percutaneous biopsies and by a standardized precise description of the location of the lesion and its pathological type, to limit the number of errors due to pathology-related issues [31].

A similar situation is breast MRI, which is rarely a standalone examination, but should end with a summary of the MRI exam and the other radiological results, as well as a recommendation for further examinations or management. It is the responsibility of the specialist breast radiologist to bring together the imaging findings rather than the multi disciplinary tumor (MDT) board to summarize the results of the different radiological modalities.

Errors due to patient factors or tumor type

Sometimes there are no technical, perceptual, or interpretative errors in a breast cancer misdiagnosis, but a mixture of contributing causes, where the cancer may be difficult to detect, such as lobular cancers. This may be mainly due to atypical features of cancer or to the background parenchyma (breast density on mammography or background parenchymal enhancement (BPE) on MRI).

Patient factors

Breast density is recognized as a risk factor for the development of breast cancer, as well as a feature that is associated with failure to identify cancers with MG [33]. Dense tissue produces a masking effect, which reduces the ability to visualize solid dense cancer in mammograms. In addition, the risk of breast cancer development in the case of dense breasts at MG is 3- to 5-fold over that of women with fatty breasts. Despite advances in mammographic techniques, such as DBT, a significant number of cancers (41%) arising in dense breasts are still mammographically occult [34].

DBT has higher cancer detection in both dense and non-dense breasts [35]. However, among women with

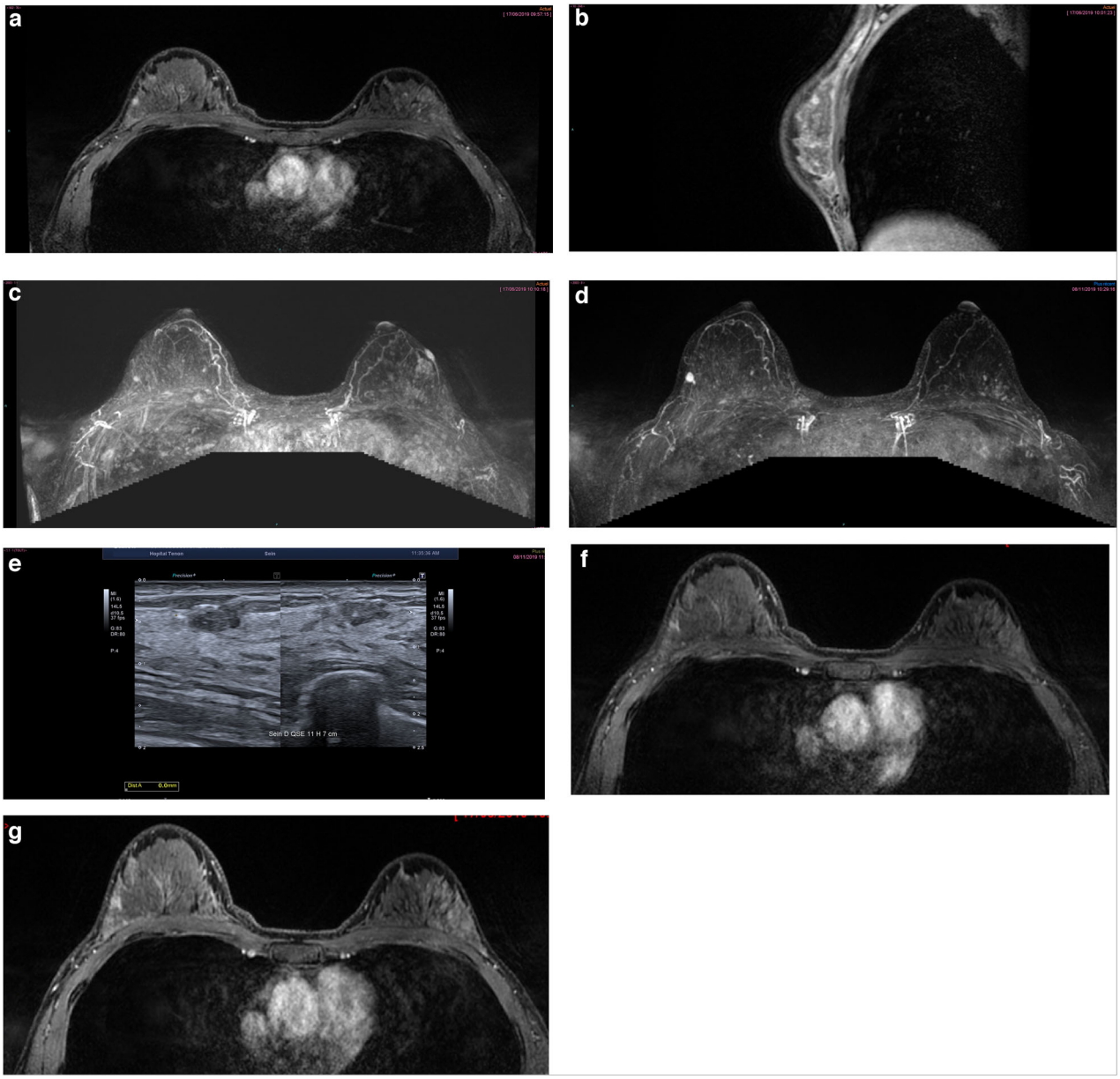

Fig. 8 Subtle triple-negative breast cancer (MR imaging). Initial MR: DCE MR sequence (axial T1W DCE MR sequence (**a**), sagittal T1W post gadolinium (**b**)): Missed and classified as BI-RADS 3 on the first MRI performed for high-risk screening. Early MIP initial MRI (**c**)/Early MIP 6 months later MRI (**d**)/ ultrasonography (**e**): Detected 6 months later at MRI and confirmed by the US. Initial MR: Early and late T1W DCE MR sequence (**f**, **g**): retrospectively, there was a blooming sign effect on the first MRI

dense breasts undergoing screening, abbreviated breast MRI, compared with DBT, was associated with a significantly higher rate of invasive breast cancer [36]. For this reason, a growing body of evidence suggests that contrast imaging techniques may benefit from supplemental screening examinations, such as MRI suggested in the EA1411 ECOG-ACRIN study [36] or in the DENSE trial [37]. Recently, the EUSOBI has suggested an MRI examination in all patients with breast density D at mammography [33]. Despite the level 1 evidence from a randomized controlled trial, MRI screening for women with extremely dense breasts is not being implemented, and misdiagnosis may thus occur in women with extremely dense breasts because these recommendations are not uniformly followed. About 10% of the screening population have breast density BIRADS D and may benefit from supplemental screening, but this equates to over 60 million women across Europe. Currently, there are

insufficient resources and capacity to offer this modality, and further roll-out is dependent on political willingness to invest in better care for these women. Differences in the availability of equipment—for example, MRI-guided biopsy, staff with experience, and the general willingness of policymakers to pay for supplemental screening tests vary from country to country and will affect the level to which any recommendations can and will be implemented. Even in the absence of national programs that offer MRI screening as part of national healthcare, women should be informed about this recommendation in an unbiased and objective way according to the principle of "shared decision-making". Nowadays, many imaging modalities exist for the diagnosis of breast cancer, including mammography (MG), US, breast MR imaging (MRI), digital breast tomosynthesis (DBT), CEM, as well as many interventional procedures. Each modality has advantages and disadvantages, and every patient benefits in slightly different ways from each of these techniques depending on her breast density (ratio gland/fibrous and fatty tissue) and on her prior probability of breast cancer. The lack of adoption of national/international recommendations may be a source of errors; A woman with very dense breast tissue may benefit from screening with mammography or DBT supplemented with MRI or US to compensate for the low sensitivity of mammography (around 60%) and significantly improvement by MRI [37]. By comparison, suggesting breast MR imaging for women with a population average risk who suffer from breast pain before the menstrual cycle exposes them to the detection of many incidental findings that may result in targeted US and possibly unnecessary interventional procedures and biopsies [38].

If breast density is a cause of increased occult cancer at mammography, marked BPE could have the same effect in MRI and CEM. BPE is a characteristic of normal breast parenchyma, describing the amount of normal fibro-glandular breast tissue that is enhanced. Normal BPE can have diffuse or nodular enhancement patterns and varies depending on the phase of the menstrual cycle. The amount of BPE that occurs is thought to be associated with endogenous hormone levels [39]. BPE might have an important effect on the diagnostic accuracy of contrast-enhanced studies, for this reason, the ACR (American College of Radiology) has included in the current BI-RADS lexicon the reporting of BPE rate; minimal (a), mild (b), moderate (c) and marked (d) [40]. In the case of moderate or marked BPE there is an increased risk that BPE could cause false negatives by obscuring malignancies or could result in false-positive results by mimicking the appearance of breast cancer [41, 42]. Moreover, many papers have reported that the increase in BPE is a risk factor for developing breast cancer, in addition to breast density [43, 44].

Tumor factors

Two types of tumors may result in diagnostic errors: slow-growing tumors and very fast-growing tumors, such as inflammatory breast cancer.

Slowly growing malignancy

Comparison with previous exams of 5–7 years earlier can be useful for depicting subtle or slow-growing changes if available [45]. Special caution should be taken with stable or decreasing indeterminate findings in patients who are taking tamoxifen, as the use of this medication may slow or arrest tumor growth. Disappearing microcalcification can also be falsely reassuring as sometimes it can be related to underlying invasive malignancy [46].

Performing a global analysis of current and previous exams by "stepping back" and evaluating all images can be useful for appreciating developing asymmetries. Small non-spiculated masses, areas of architectural distortion and asymmetry, and small clusters of amorphous or faint microcalcifications may all be difficult to perceive. To avoid perception error, images should be reviewed as mirror images, with mediolateral oblique images placed together and craniocaudal images placed together [47–49]. The radiologist should compare areas on the side-by-side images to identify any focal asymmetric density or low-density mass. Identification of a focal density should prompt a search for this density on the corresponding view in the same arc from the nipple. Additional views may be needed to verify the presence of a true lesion, such as spot compression with or without DBT or DBT views in cases of architectural distortions or asymmetric densities. Any asymmetric density that is newly increasing, or with new associated suspicious findings (e.g., calcifications, architectural distortion) and/or that corresponds to a palpable finding should be further investigated. Radiologists should have a higher level of suspicion in cases of asymmetries that are only seen on the craniocaudal (CC) view owing to better parenchymal compression in this incidence. There should also be a high level of suspicion in cases of an asymmetry in an area of the breast that is normally well visualized on only one view (eg, posteromedial region of the breast, axillary tail, or inframammary fold) [18].

Clusters of microcalcifications are better appreciated in magnified orthogonal views. The slow evolution may also explain why microcalcifications are the most common mammographic sign to be missed or misinterpreted when the radiologist is considered to be at fault in medical issues [50]. The comparison must be performed with mammography performed several years before if available.

Table 2 EUSOBI recommendations to limit misdiagnosis errors in breast imaging

Causes of errors	How to minimize the errors
Technical failures: positioning, compression, inadequate exposure factors, protocol misuse (20% of errors, 17% of malpractice claims)	• Double reading • Quality criteria • Periodic external audit of MG unit • Dedicated training for MG quality control for technologists and radiologists
Lack of consideration of clinical context (a breast palpable mass is found in 80% of malpractice claims)	• Improve communication with a patient with the use of questionaries, including the date of previous MG, personal and familial history, and clinical symptoms (always listen carefully) • Clinical examination (palpable nodule, inflammation, nipple discharge, skin retraction).
Detection errors or misapplication of BI-RADS score (perception errors) (5% of errors in UK programs including management errors)	• Limit distraction: quiet reading room, limit the frequency of interruptions (phone call) • Limit fatigue: do not read too many MG in a day • Confidence: do not rely on AI entirely, be wary of satisfaction of search • Radiologist training: a minimal number of MG per year, sub-specialization in breast radiology, dedicated breast imaging course • Systematic personal analysis • Applying national and international recommendations
False reassurance	• Be rigorous in correlating position between modalities • To use marker after biopsy
Errors due to pathology-related or MDT-related issues (false-negative rates described in 1–4% of breast percutaneous biopsies)	• Communication between radiologist and pathologist (Weekly Radio-pathological correlation session) • Standardized report (radiology report should have precise location and type of lesion/pathology report should state the presence of microcalcifications in the stereotactic samples …)
Type of tumor Benign-looking breast cancer (TNBC) (10–20% of invasive cancers) Inflammatory breast (1–5% of cancers)	• Consider clinical context + + + • Correlation between modalities + + • Be careful with lesion margins + +
Missed cancer due to background parenchyma High dense breast (10% of patients have a breast density D) Intense BPE	• Complete with IV exam (MRI, CEM) • Ultrafast protocol
Management errors	• Communication with the patient: have a face-to-face meeting with the patient to explain the results • Communication with other specialists: meeting session with a dedicated MDT session for breast cancer

Although DBT might also depict and characterize microcalcifications in a satisfactory way, magnified views might still be needed.

Inflammatory breast

Inflammatory breast carcinoma (IBC). IBC is a rare and aggressive malignancy that is often initially misdiagnosed because of its similar presentation to more benign breast pathologies [51], such as mastitis, resulting in treatment [52, 53]. As a consequence, physicians suspect cancer may be wrongly reassured by false-negative findings on a mammogram [54]. Our recommendation, based on the literature reviewed [55, 56], is that any patient with presumed benign mastitis that does not rapidly resolve with recommended therapy for benign disease should undergo breast imaging with mammography and US, followed by MRI if available, and biopsy.

Triple-negative breast cancers

Last but not least, there is the issue of triple-negative breast cancers (TNBCs). Benign-looking breast cancers that correspond to well-circumscribed lesions may correspond to triple-negative breast carcinomas [57, 58]. Again, the context is crucial. A new benign-looking mass in a post-menopausal or elderly woman or in women with genetic mutation should prompt a biopsy instead of a follow-up. TNBC, characterized by estrogen receptor, progesterone receptor, and HER2 negativity, is also a biologically and clinically aggressive tumor characterized by early onset (usually < 50 years old women) and frequent association with BRCA 1 mutation. In spite of the aggressiveness, TNBC can mimic benign lesions at conventional breast imaging, lacking the typical malignant features of cancer. Most triple-negative tumors are masses (81.1%) characterized by round shape (86.7%),

non-circumscribed margins (90%), and rim enhancement (73.3%) [59]. Due to the benign-like appearance of triple-negative cancer, biopsy is strongly recommended in any high-risk patients with a new mass detected on MRI, particularly if this mass is located in the posterior part of the breast (Fig. 8).

Conclusion

In conclusion, various factors are responsible for misdiagnosis in breast cancers, including faults in the radiologist's practice (technical failures, lack of consideration of clinical context, misapplication of BI-RADS score, false reassurance), lack of communication with other specialists or with the patient, and the type of tumor or breast parenchyma. This work provides guidance in a clear and concise way about the main causes of misdiagnosis and offers some suggestions on how to minimize such errors (Table 2), thus offering assistance to radiologists in their daily practice of breast imaging.

Abbreviations

AI	Artificial intelligence
BI-RADS	Breast Imaging Reporting Data System
BPE	Background parenchymal enhancement
CC	Cranio caudal
CEM	Contrast-enhanced mammography
DBT	Digital breast tomosynthesis
DM	Digital mammography
EUSOBI	European Society of Breast Imaging
MDT board	Multi disciplinary tumor board
MLO	Mediolateral oblique
MRI	Magnetic resonance imaging
TNBC	Triple-negative breast cancer
US	Ultrasonography

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Compliance with ethical standards

Guarantor

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Conflict of interest

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Statistics and biometry

No complex statistical methods were necessary for this paper.

Informed consent

Written informed consent was not required for this study.

Ethical approval

Institutional Review Board approval was not required.

Study subjects or cohorts overlap

Not applicable.

Methodology

- Review

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on behalf of EUSOBI Board

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