
UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO

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# *L'imaging di stadiazione*

# IMAGING

## MORPHOLOGICAL TECHNIQUES

Mammography / DBT

US / ABUS

## DYNAMIC TECHNIQUES

MR

CEM

# IMAGING PREOPERATORIO STAGING

- T SIZE
- MULTIFOCALITA’
- MULTICENTRICITA’
- BILATERALITA’
- CDIS – RICERCA CI
- CI – VALUTAZIONE ESTENSIONE COMPONENTE IN SITU

# IMAGING SENZA MDC

- DBT
- US
- ABUS

# Digital Breast Tomosynthesis in the Diagnostic Setting: Indications and Clinical Applications[1]

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*Brandi E. Nicholson, MD*
*Carrie M. Rochman, MD*
*Judith K. Merchant, MD*
*Ray C. Mayo III, MD*
*Jennifer A. Harvey, MD*

**Abbreviations:** BI-RADS = Breast Imaging Reporting and Data System, DBT = digital breast tomosynthesis, FDA = Food and Drug Administration, FFDM = full-field digital mammography, MLO = mediolateral oblique, 3D = three-dimensional, 2D = two-dimensional

**RadioGraphics 2015**; 35:975–990

Digital breast tomosynthesis (DBT) is an emerging technology used in diagnostic breast imaging to evaluate potential abnormalities. In DBT, the compressed breast tissue is imaged in a quasi–three-dimensional manner by performing a series of low-dose radiographic exposures and using the resultant projection image dataset to reconstruct cross-sectional in-plane images in standard mammographic views. Improved visualization of breast detail at diagnostic DBT allows improved characterization of findings, including normal structures and breast cancer. This technology reduces the summation of overlapping breast tissue, which can mimic breast cancer, and provides improved detail of noncalcified mammographic findings seen in breast cancer. It also assists in lesion localization

# DBT INDICATIONS

- Lesion visibility
- Replacement for Traditional Supplemental Imaging
- **Assessment of Noncalcified Cancers**
  - *Architectural Distortion*
  - *Focal Asymmetry*
  - *Masses*
- **Localization of Single-View Findings**
- **Breast Cancer Staging**

# DBT INDICATIONS

- *Tumor Size*
- *Number of Tumor Lesions or Satellite Lesions*
- *Evaluation of the Contralateral Breast*
- *After MRI*

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BREAST RADIOLOGY

# Digital breast tomosynthesis (DBT): recommendations from the Italian College of Breast Radiologists (ICBR) by the Italian Society of Medical Radiology (SIRM) and the Italian Group for Mammography Screening (GISMa)

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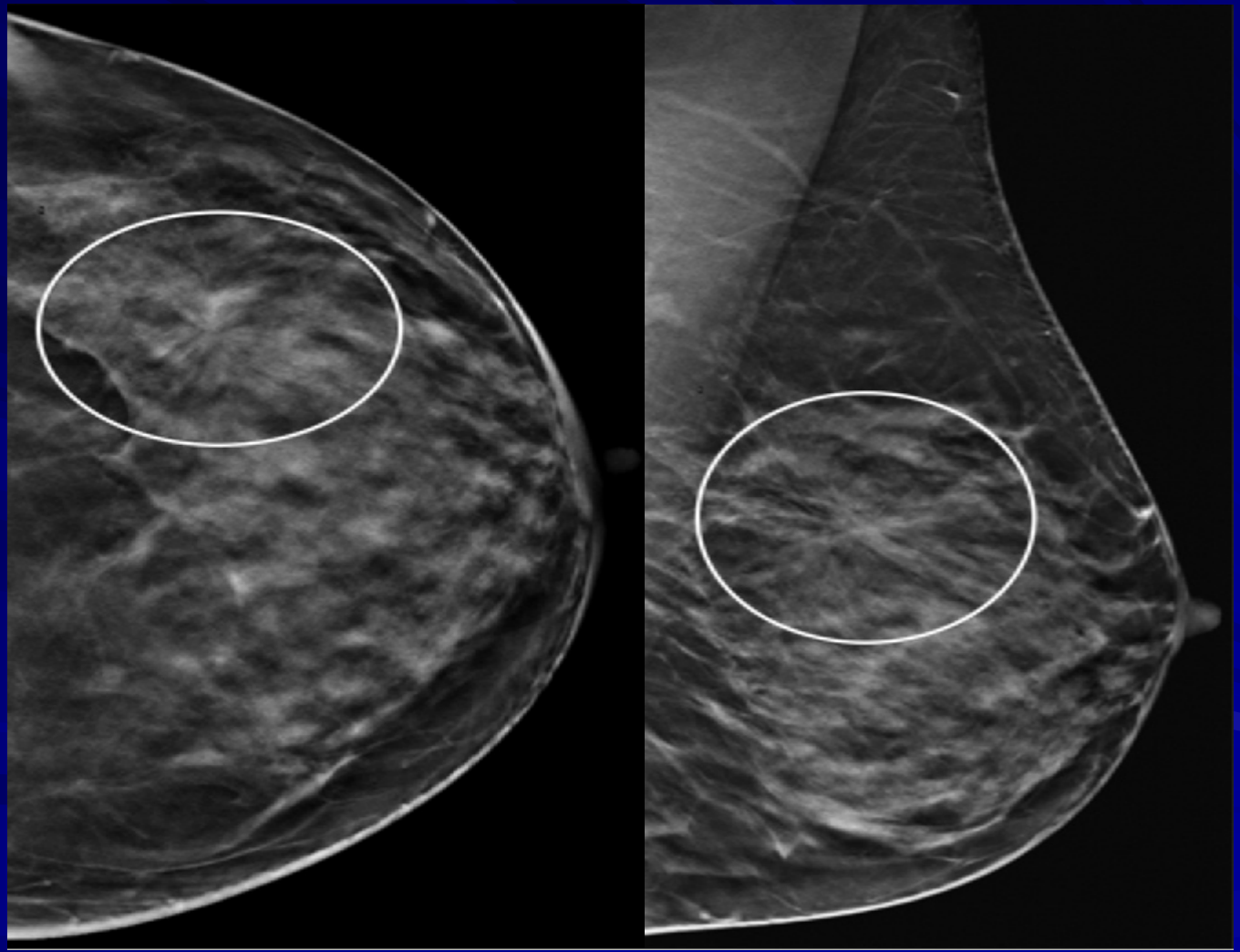

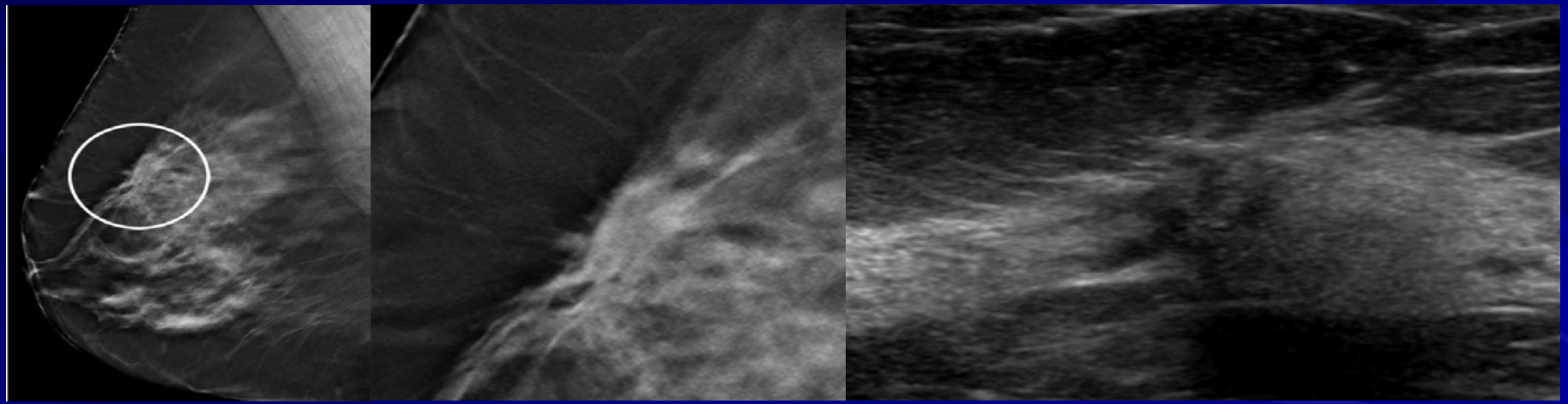

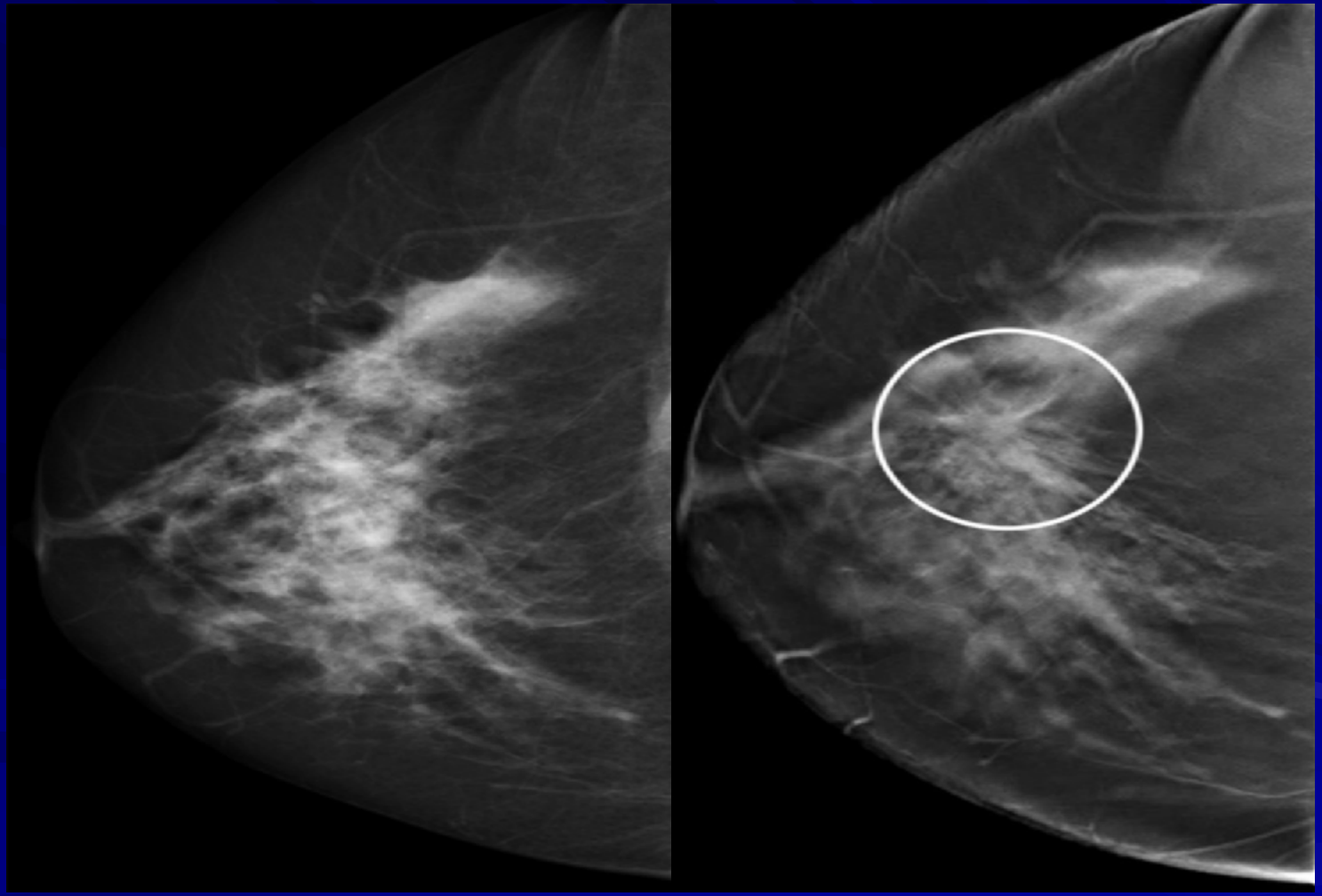

ORIGINAL RESEARCH • BREAST IMAGING

Radiology

# Local Tumor Staging of Breast Cancer: Digital Mammography versus Digital Mammography Plus Tomosynthesis

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Conflicts of interest are listed at the end of this article.

See also the editorial by Moy in this issue.

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***Background:*** Combined digital mammography (DM) and digital breast tomosynthesis (DBT) (hereafter, DM plus DBT) has increased cancer detection rates when compared with those achieved with DM-only screening. However, there is limited literature on DBT as an adjunct to mammography in the staging of known breast cancers.

***Purpose:*** To compare the diagnostic accuracy of DM alone with that of DM plus DBT in the identification of additional ipsilateral and contralateral lesions in women with newly diagnosed breast cancer.

***Materials and Methods:*** This prospective study (*https://clinicaltrials.gov*, NCT01881880) included 166 women with breast cancer (mean age, 59.5 years ± 11; age range, 40–87 years) and used the aforementioned techniques, with breast MRI and pathologic verification of all suspected lesions as the reference standards. Four radiologists independently reviewed the DM and DM plus DBT images using the American College of Radiology Breast Imaging Reporting and Data Systems criteria for diagnosis of index lesions and presence of additional disease. Sensitivity, specificity, and area under the receiver operating characteristic curve (AUC) obtained for DM and DM plus DBT were compared by using the McNemar test.

***Results:*** Twenty-four women (14%) exhibited multifocal lesions; 20 (12%), multicentric lesions; 39 (23%), additional ipsilateral lesions; and 18 (11%), bilateral lesions. The sensitivities were higher for DM plus DBT than for DM in the diagnosis of multicentric (51% [41 of 80] vs 37% [30 of 80], $P = .002$) and additional ipsilateral (52% [81 of 156] vs 44% [69 of 156], $P = .007$) lesions. The AUC was larger for DM plus DBT than for DM (0.74 vs 0.67, $P = .02$) in the diagnosis of bilateral breast cancer. No significant differences in specificity were noted. The added diagnostic value of DBT was limited to the group of women with nondense breasts: For diagnosis of ipsilateral lesions, AUC of DM plus DBT versus DM was 0.74 versus 0.70 ($P = .04$). For diagnosis of contralateral lesions, AUC of DM plus DBT verus DM was 0.76 versus 0.68 ($P = .02$).

***Conclusion:*** The combination of digital mammography with digital breast tomosynthesis improves diagnostic accuracy for additional ipsilateral and contralateral breast cancer in women with nondense breasts.

**Table 5: Diagnostic Performance of DM and DM Plus DBT for Ipsilaterality Staging according to Breast Density**

| | Nondense Breast Tissue | | | Dense Breast Tissue | | |
|---|---|---|---|---|---|---|
| Statistic | DM | DM Plus DBT | *P* Value | DM | DM Plus DBT | *P* Value |
| Sensitivity (%) | 47 [38, 57] (55/116) | 57 [47, 66] (65/116) | <.01 | 35 [21, 52] (14/40) | 40 [25, 57] (16/40) | .48 |
| Specificity (%) | 88 [84, 92] (303/340) | 89 [85, 92] (304/340) | .76 | 94 [89, 97] (158/168) | 96 [91, 98] (161/168) | .44 |
| AUC | 0.70 [0.64, 0.76] | 0.74 [0.68, 0.80] | .04 | 0.64 [0.53, 0.74] | 0.64 [0.54, 0.74] | .93 |

Note.—Sensitivity and specificity are reported as percentages, with the 95% confidence interval in brackets and the raw numbers (numerator/denominator) in parentheses. AUC = area under the receiver operating characteristic curve, DBT = digital breast tomosynthesis, DM = digital mammography.

**Table 6: Diagnostic Performance of DM and DM Plus DBT for Bilaterality Staging according to Breast Density**

| | Nondense Breast Tissue ($n$ = 48) | | | Dense Breast Tissue ($n$ = 24) | | |
|---|---|---|---|---|---|---|
| Statistic | DM | DM Plus DBT | *P* Value | DM | DM Plus DBT | *P* Value |
| Sensitivity | 48 [33, 63] (23/48) | 58 [43, 72] (28/48) | .61 | 46 [26, 66] (11/24) | 50 [29, 71] (12/24) | .65 |
| Specificity | 89 [85, 92] (362/408) | 89 [85, 92] (361/408) | .84 | 90 [85, 95] (166/184) | 87 [80, 91] (160/184) | .18 |
| AUC | 0.68 [0.59, 0.76] | 0.76 [0.67, 0.84] | .02 | 0.65 [0.53, 0.78] | 0.70 [0.58, 0.82] | .40 |

Note.—Sensitivity and specificity are reported as percentages, with the 95% confidence interval in brackets and the raw numbers (numerator/denominator) in parentheses. AUC = area under the receiver operating characteristic curve, DBT = digital breast tomosynthesis, DM = digital mammography.

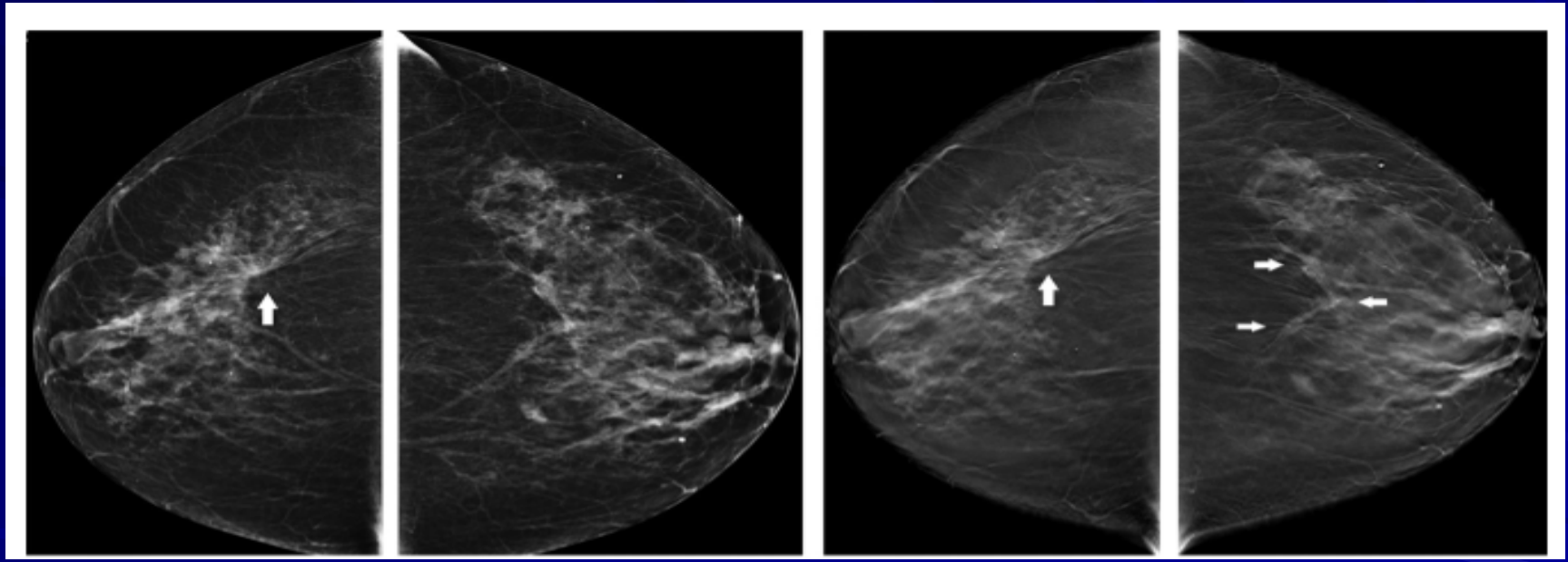

## Summary

In women with newly diagnosed breast cancer and nondense breast tissue, combined digital mammography and digital breast tomosynthesis has higher sensitivity than digital mammography alone for multifocal or multicentric disease and higher diagnostic performance regarding the presence of bilateral disease; however, it does not significantly affect specificity.

## Key Points

- Sensitivity was higher for combined digital mammography (DM) and digital breast tomosynthesis (DBT) (hereafter, DM plus DBT) than for DM alone in the diagnosis of multicentric (51% vs 37%, $P = .002$) and additional ipsilateral (52% vs 44%, $P = .007$) lesions.
- The diagnostic performance of DM plus DBT was greater than that of DM alone in the assessment of bilateral breast cancer (area under the receiver operating characteristic curve [AUC], 0.74 vs 0.67; $P = .02$).
- The diagnostic performance of DBT plus DM was greater than that of DM alone only in women with nondense breasts; AUC was 0.74 versus 0.70 ($P = .04$) for ipsilateral lesions and 0.76 versus 0.68 ($P = .02$) for contralateral lesions.


Digital mammography (DM) plus digital breast tomosynthesis had higher sensitivity than DM for breast cancer staging regarding the diagnosis of multifocal or multicentric lesions and higher area under the receiver operating characteristic curve regarding the presence of bilateral lesions, without any change in specificity. This advantage was restricted to women with nondense breasts.



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Research article

# Preoperative breast cancer staging with multi-modality imaging and surgical outcomes

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ABSTRACT

*Purpose:* To compare the rates of mastectomy and re-operation after breast-conserving surgery (BCS) among patients who had different pre-operative multi-modality imaging, hence identifying significant predictors of mastectomy and re-operations within each group.
*Method:* Retrospective study of consecutive patients with primary breast cancer treated January 2010 – December 2016, divided in 3 groups, undergoing pre-operative local staging respectively with conventional imaging modalities only (2D mammography, ultrasound (US)), conventional imaging and tomosynthesis (DBT) and/or MRI. The primary outcome was identification of significant predictors of surgical outcomes, within each group. Study variables examined in univariate analysis were age, lesion dimension, breast density, multifocality, tumor size, histology, and if associated with outcomes they were included in binary logistic regression analysis.
*Results:* Amongst 1547 patients, patient and tumor characteristics differed across the three groups, as did mastectomy rates which were 18 % (102/562) for 2D + US, 36 % (154/428) for 2D + DBT + US, 45 % (250/557) for 2D +/-DBT + US + MRI($p < 0.001$). Variables strongly associated with mastectomy were larger lesions and multifocality (as was multi-modality group). Re-operation rate showed an opposite trend: 12.2 % (56/459) for 2D + US, 8 % (22/272) for 2D + DBT + US, 6.5 % (20/306) for 2D +/-DBT + US + MRI. Re-operation rate for 2D +/-DBT + US + MRI was lower than for 2D + US ($p = 0.01$) but similar to 2D + DBT + US ($p = 0.58$). Patients who had 2D + US and re-operations had significantly larger lesions, more underestimation, higher proportion of invasive carcinoma with in-situ component than those who did not require re-operation.
*Conclusions:* Patients who had larger tumors and multifocal disease were more frequently staged by adding DBT and/or MRI to conventional imaging (mammography and US) which was associated with more extensive surgical treatment but lower reoperation rates.

Breast cancer (BC) treatment involves a multidisciplinary and multimodality management, with surgery being the primary local treatment for early stage BC. The surgical strategy depends on several factors, including the clinical and radiological evaluation of the stage of the disease, and also the patient's preferences. The role of mammography and ultrasonography is firmly established for initial diagnosis (and hence also in preoperative imaging) of BC; however, there is ongoing controversy about the role of preoperative magnetic resonance imaging (MRI) in further assessing disease extent in newly diagnosed patients [1]. This issue is now gaining more relevance with the entry of digital breast tomosynthesis (DBT) into BC screening, and also as an additional modality in the preoperative imaging pathway of newly diagnosed BC patients.

Low local recurrence rates and the improvement of this parameter over time can be attributed to many factors, including careful preoperative breast imaging staging, adequate surgical margins, radiotherapy, and adjuvant systemic therapy [2–5]. Ensuring adequate surgical margins is fundamental to breast-conserving surgery (BCS) for both invasive BC and ductal carcinoma in situ [6], but this is not always achieved, and a considerable number of patients have involved margins and residual postoperative disease [7], leading to re-excision surgery or mastectomy. Re-excision rates following BCS are variable between 0 % and 50 %, with a mean of 20–23 % in several large national databases [8].

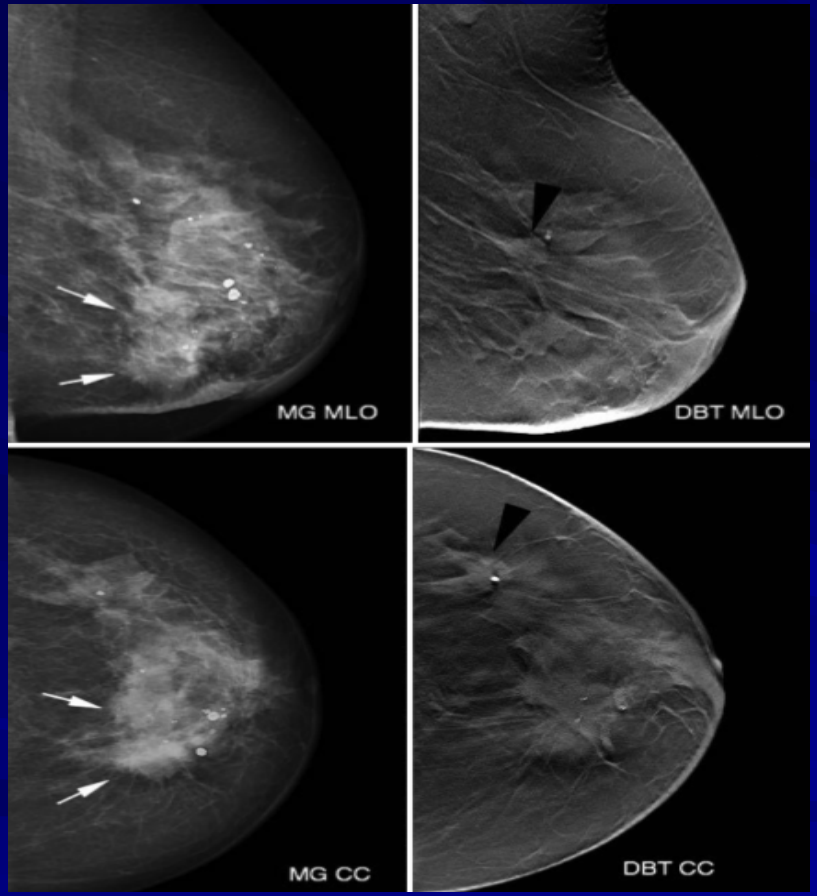
Breast MRI has been proposed for BC staging and treatment planning [5] on the premise that it might improve surgical care. Studies have demonstrated its superior sensitivity in assessing tumor size and detecting multifocal and multicentric disease [9–11], showing a sensitivity for detection of index lesions ranging between 93%–98% compared with 83%–86% for mammography and 71%–75% for ultrasound [12]. MRI is also more accurate in detecting invasive lobular carcinoma [13]. However, despite MRI's detection capability in the preoperative setting, there is less clarity on whether it improves initial surgical outcomes in BC and whether it reduces unnecessary re-operations: meta-analysis [1] reported consistent evidence that MRI was significantly associated with increased odds of receiving mastectomy [OR 1.39 (95 %CI 1.23, 1.57], while there was no statistical evidence that MRI had an effect on the odds of re-excision, or the odds of positive margins in those who received BCS. Another gap in the evidence is whether DBT influences surgical outcomes when integrated into the pre-operative assessment of BC patients. Because of its relatively recent clinical application, little is known about DBT's contribution in BC staging, and how it stands relative to 2D + US or MRI [14–17].

The multivariate analysis evidenced significative differences on surgical outcomes in patients affected by larger tumors or multifocal disease, invasive cancer with in-situ component, staged with addiction of DBT and/or MRI to conventional digital mammography combined with ultrasound.

This leaded by one hand to more extensive surgery (higher rates of mastectomy) and on the other hand to significantly lower reoperation margins.

- ✓ DBT in addition to mammography can significantly improve preoperative local staging of breast cancer, especially in patients with dense breasts.
- ✓ DBT is superior to mammography in the detection of the primary lesion and detects significantly more additional tumor sites in dense breasts.
- ✓ This may aid in determining optimal treatment in these patients, i.e.a more appropriate selection of patients better served with mastectomy rather than a breast-conserving therapy approach.
- ✓ Applying DBT in addition to mammography as part of the preoperative work-up of breast cancer in patients with dense breasts may be a cost- and time-effective alternative, especially if preoperative breast MRI is not available or patients have contraindications for MRI.
- ✓ However, the sensitivity cannot exceed that of breast MRI and limitations have to be expected in the case of invasive lobular carcinoma.

Krammer J et al. ANTICANCER RESEARCH 37: 5255-5261 (2017)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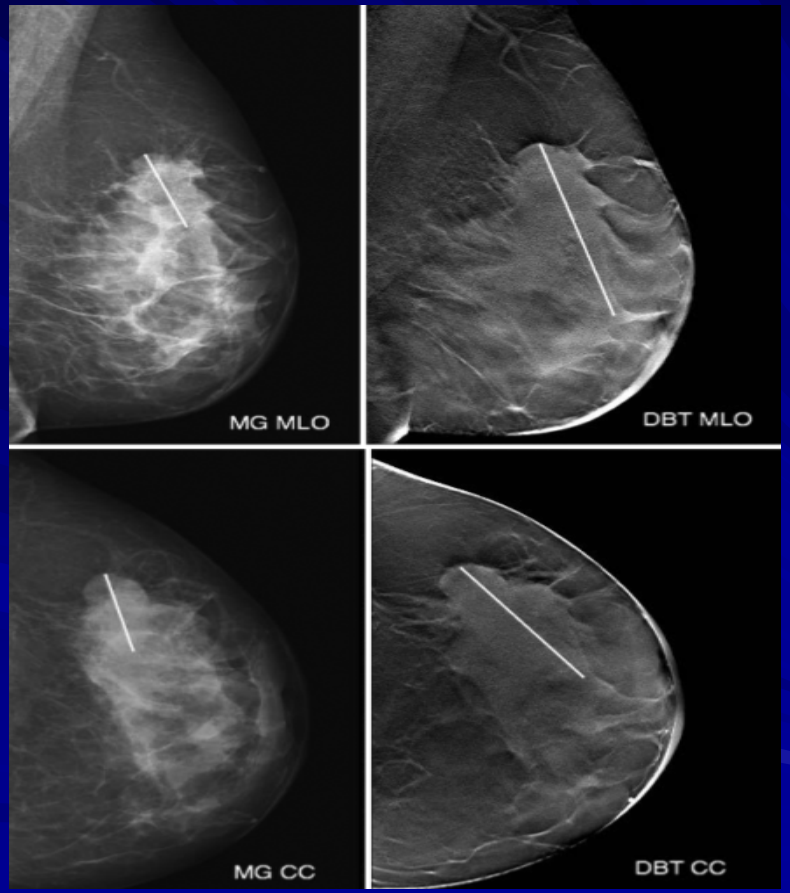
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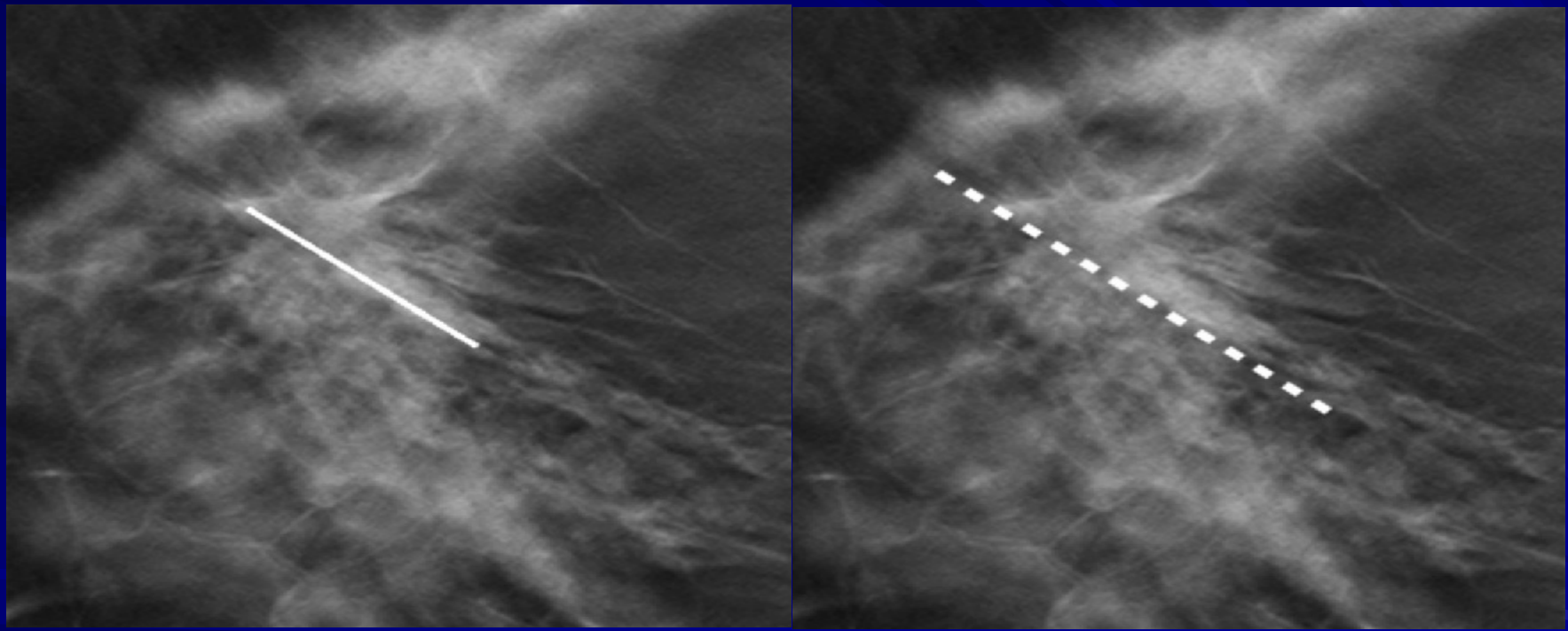

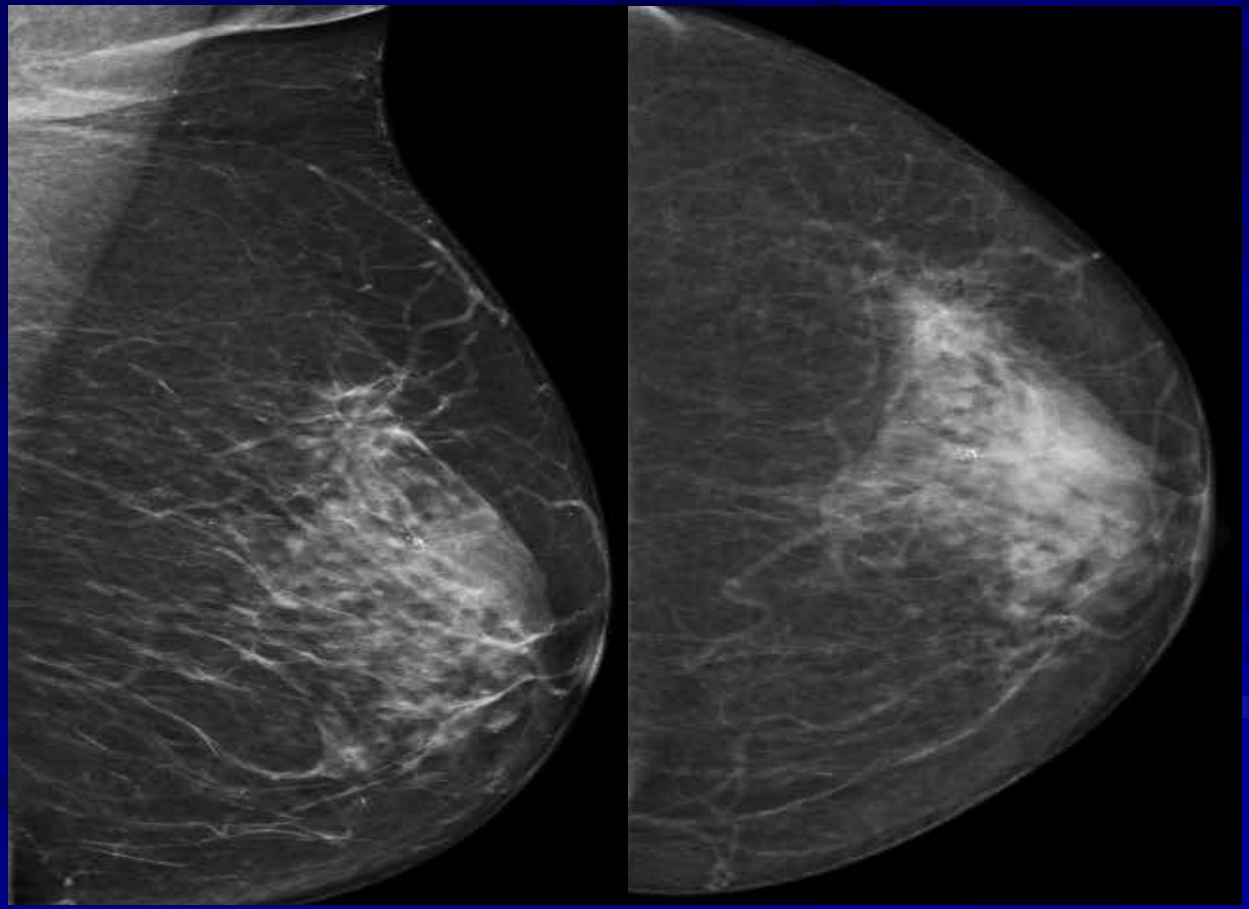

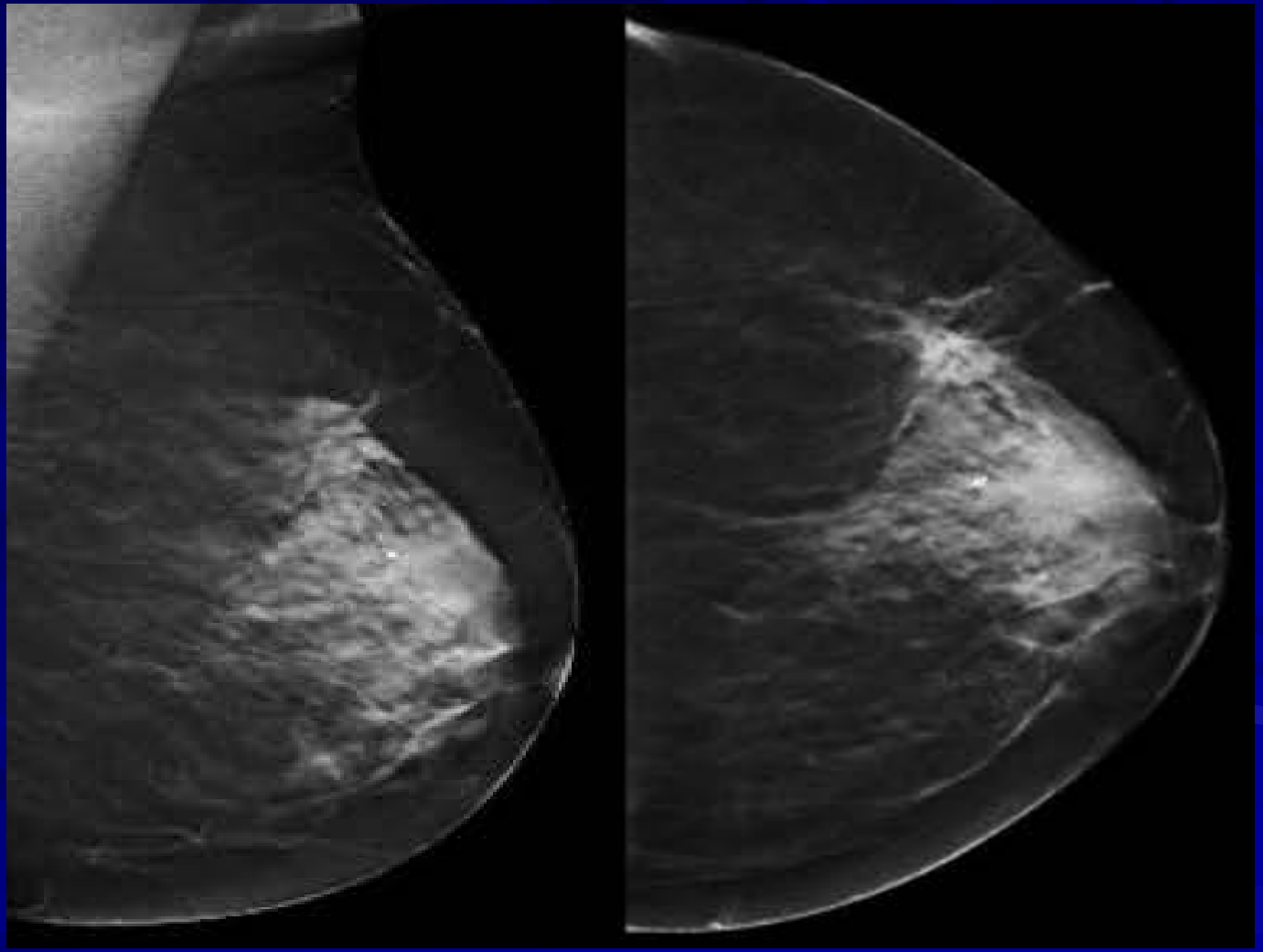

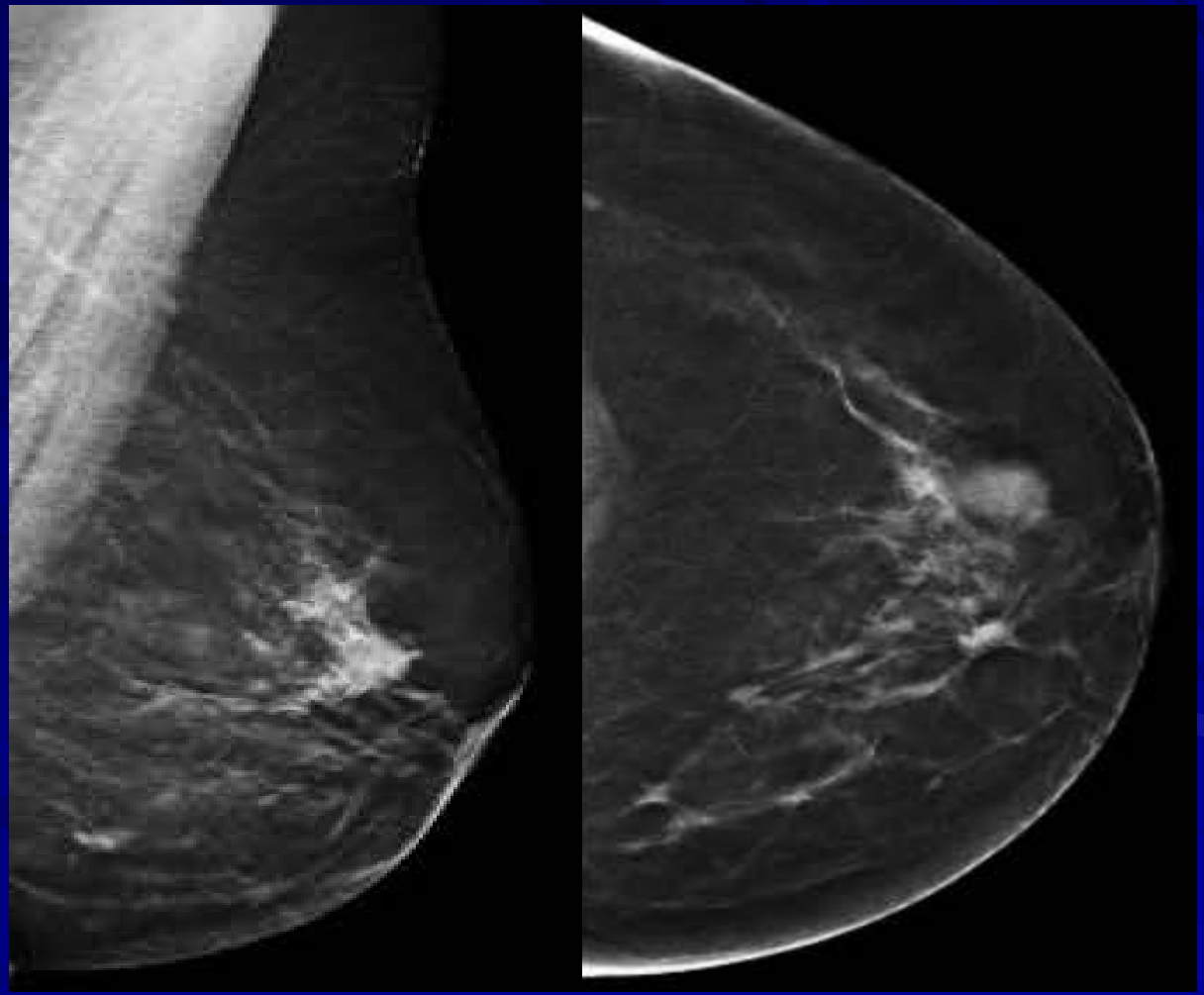

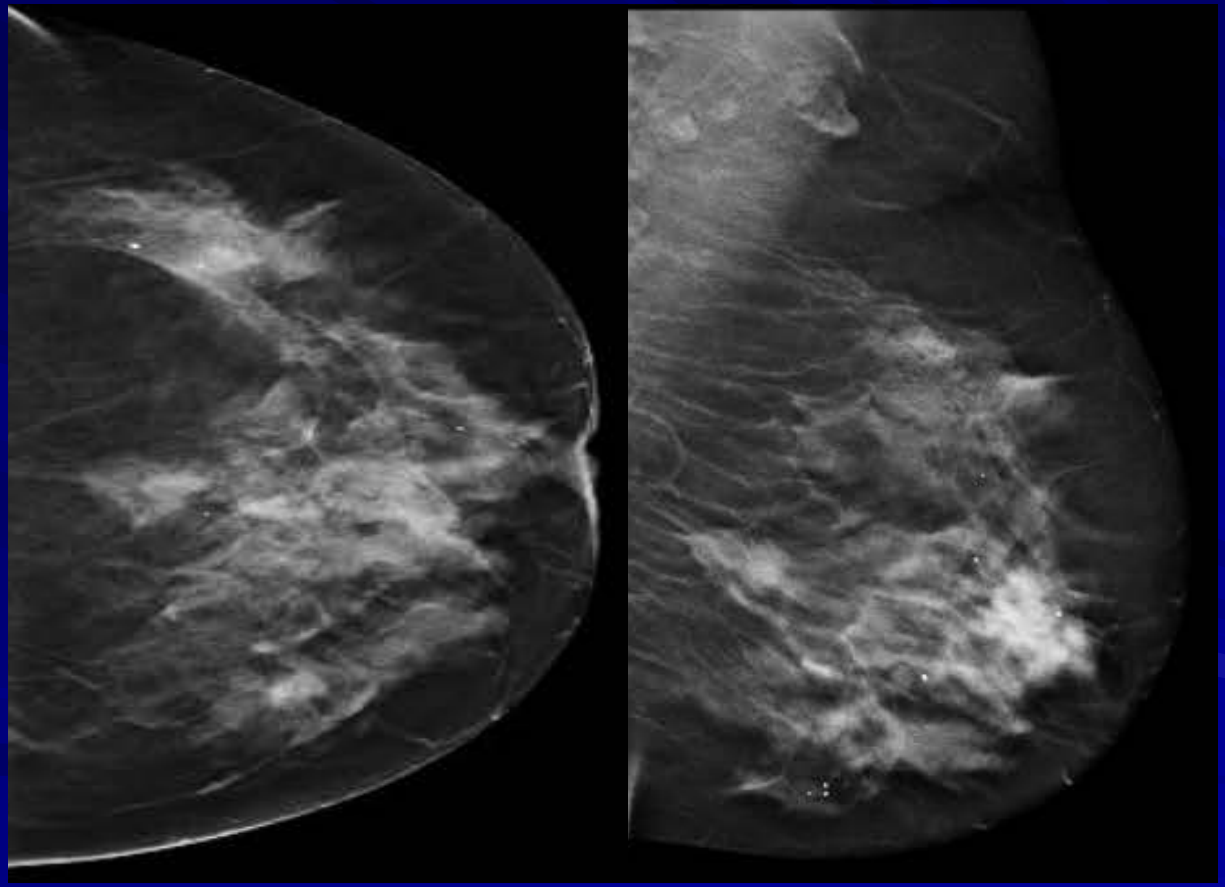

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Original article

# Preoperative assessment of breast cancer: Multireader comparison of contrast-enhanced MRI versus the combination of unenhanced MRI and digital breast tomosynthesis

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ABSTRACT

*Purpose:* To compare the sensitivity for breast cancer (BC) and BC size estimation of preoperative contrast-enhanced magnetic resonance imaging (CEMRI) versus combined unenhanced magnetic resonance imaging (UMRI) and digital breast tomosynthesis (DBT).

*Patients and methods:* We retrospectively included 56 women who underwent DBT and preoperative 1.5 T CEMRI between January 2016–February 2017. Three readers with 2–10 years of experience in CEMRI and DBT, blinded to pathology, independently reviewed CEMRI (diffusion-weighted imaging [DWI], T2-weighted imaging, pre- and post-contrast T1-weighted imaging) and a combination of UMRI (DWI and pre-contrast T1-weighted imaging) and DBT. We calculated per-lesion sensitivity of CEMRI and UMRI + DBT, and the agreement between CEMRI, UMRI and DBT versus pathology in assessing cancer size (Bland-Altman analysis). Logistic regression was performed to assess features predictive of cancer missing.

*Results:* We included 70 lesions (64% invasive BC, 36% ductal carcinoma in situ or invasive BC with in situ component). UMRI + DBT showed lower sensitivity (86–89%) than CEMRI (94–100%), with a significant difference for the most experienced reader only ($p = 0.008$). False-positives were fewer with UMRI + DBT (4–5) than with CEMRI (18–25), regardless of the reader ($p = 0.001$–$0.005$). For lesion size, UMRI showed closer limits of agreement with pathology than CEMRI or DBT. Cancer size ≤1 cm was the only independent predictor for cancer missing for both imaging strategies (Odds ratio 8.62 for CEMRI and 19.16 for UMRI + DBT).

*Conclusions:* UMRI + DBT showed comparable sensitivity and less false-positives than CEMRI in the preoperative assessment of BC. UMRI was the most accurate tool to assess cancer size.

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Cognitive Systems Research 53 (2019) 3–19

Cognitive Systems RESEARCH

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# A performance comparison between shallow and deeper neural networks supervised classification of tomosynthesis breast lesions images

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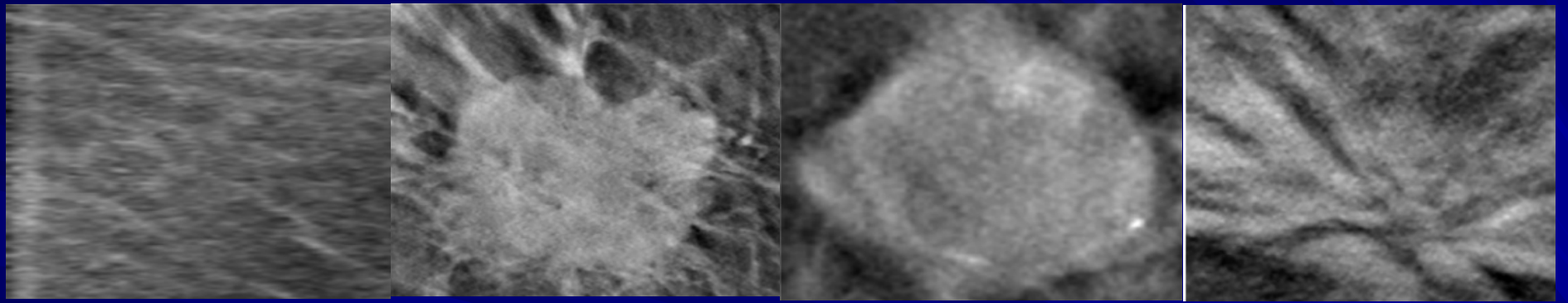
**Abstract**

Computer Aided Decision (CAD) systems, based on 3D tomosynthesis imaging, could support radiologists in classifying different kinds of breast lesions and then improve the diagnosis of breast cancer (BC) with a lower X-ray dose than in Computer Tomography (CT) systems.

In previous work, several Convolutional Neural Network (CNN) architectures were evaluated to discriminate four different classes of lesions considering high-resolution images automatically segmented: (a) irregular opacity lesions, (b) regular opacity lesions, (c) stellar opacity lesions and (d) no-lesions. In this paper, instead, we use the same previously extracted relevant Regions of Interest (ROIs) containing the lesions, but we propose and evaluate two different approaches to better discriminate among the four classes.

In this work, we evaluate and compare the performance of two different frameworks both considering supervised classifiers topologies. The first framework is feature-based, and consider morphological and textural hand-crafted features, extracted from each ROI, as input to optimised Artificial Neural Network (ANN) classifiers. The second framework, instead, considers non-neural classifiers based on automatically computed features evaluating the classification performance extracting several sets of features using different Convolutional Neural Network models.

Final results show that the second framework, based on features computed automatically by CNN architectures performs better than the first approach, in terms of accuracy, specificity, and sensitivity.



Sensitivity and specificity for the lesions evaluated through 1-vs-all approach.

| | Ori vs all | | Oro vs all | | Ost vs all | |
|---|---|---|---|---|---|---|
| | Sensitivity | Specificity | Sensitivity | Specificity | Sensitivity | Specificity |
| VGG-F | 98.67% | 97.07% | 96.01% | 95.98% | 97.24% | 96.93% |
| VGG-M | 98.14% | 96.64% | 95.00% | 95.76% | 97.18% | 96.62% |
| VGG-S | 98.36% | 97.13% | 95.61% | 96.33% | 96.67% | 97.25% |

| | KNN | LDA | LINEAR SVM | NAÏVE BAYES | DECISION TREES |
|---|---|---|---|---|---|
| VGG-F | $91.63 \pm 0.41$ | $64.57 \pm 0.66$ | $67.29 \pm 2.02$ | $43.82 \pm 0.59$ | $59.68 \pm 1.07$ |
| VGG-M | $90.74 \pm 0.48$ | $66.25 \pm 0.60$ | $69.50 \pm 2.16$ | $42.85 \pm 0.57$ | $57.03 \pm 0.98$ |
| VGG-S | $92.02 \pm 0.48$ | $65.24 \pm 0.80$ | $68.84 \pm 1.89$ | $44.89 \pm 0.60$ | $56.16 \pm 0.93$ |

applied sciences

MDPI

*Artide*

# Shape-Based Breast Lesion Classification Using Digital Tomosynthesis Images: The Role of Explainable Artificial Intelligence

**Sardar Mehboob Hussain [1,†], Domenico Buongiorno [1,2,†], Nicola Altini [1], Francesco Berloco [1], Berardino Prencipe [1], Marco Moschetta [3], Vitoantonio Bevilacqua [1,2,*] and Antonio Brunetti [1,2]**

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† These authors contributed equally to this work.

**Abstract** Computer-aided diagnosis (CAD) systems can help radiologists in numerous medical tasks including classification and staging of the various diseases. The 3D tomosynthesis imaging technique adds value to the CAD systems in diagnosis and classification of the breast lesions. Several convolutional neural network (CNN) architectures have been proposed to classify the lesion shapes to the respective classes using a similar imaging method. However, not only is the black box nature of these CNN models questionable in the healthcare domain, but so is the morphological-based cancer classification, concerning the clinicians. As a result, this study proposes both a mathematically and visually explainable deep-learning-driven multiclass shape-based classification framework for the tomosynthesis breast lesion images. In this study, authors exploit eight pretrained CNN architectures for the classification task on the previously extracted regions of interests images containing the lesions. Additionally, the study also unleashes the black box nature of the deep learning models using two well-known perceptive explainable artificial intelligence (XAI) algorithms including Grad-CAM and LIME. Moreover, two mathematical-structure-based interpretability techniques, i.e., t-SNE and UMAP, are employed to investigate the pretrained models' behavior towards multiclass feature clustering. The experimental results of the classification task validate the applicability of the proposed framework by yielding the mean area under the curve of 98.2%. The explanability study validates the applicability of all employed methods, mainly emphasizing the pros and cons of both Grad-CAM and LIME methods that can provide useful insights towards explainable CAD systems.

**Keywords:** breast cancer; deep learning; explainable AI; Grad-CAM; LIME; t-SNE; UMAP; tomosynthesis; mammography; DBT; CNN; shape classification



**Citation:** Hussain, S.M.; Buongiorno, D.; Altini, N.; Berloco, F.; Prencipe, B.; Moschetta, M.; Bevilacqua, V.; Brunetti, A. Shape-Based Breast Lesion Classification Using Digital Tomosynthesis Images: The Role of Explainable Artificial Intelligence. *Appl. Sci.* **2022**, *12*, 6230. https://doi.org/10.3390/app12126230

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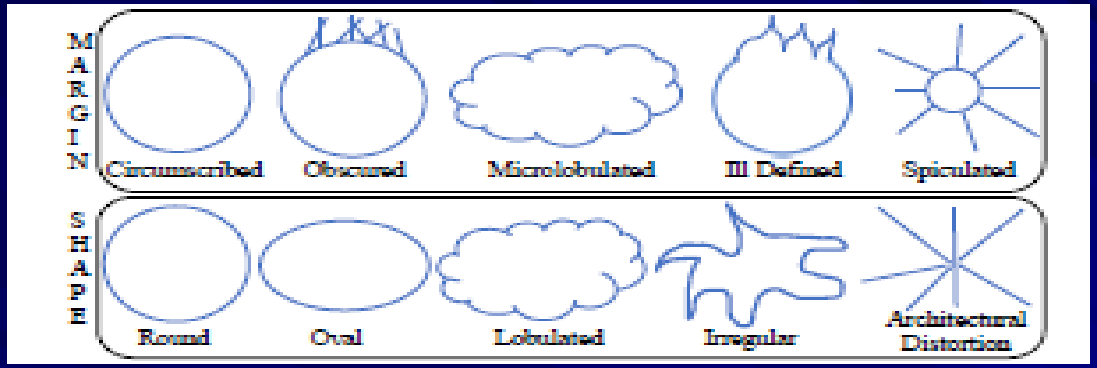
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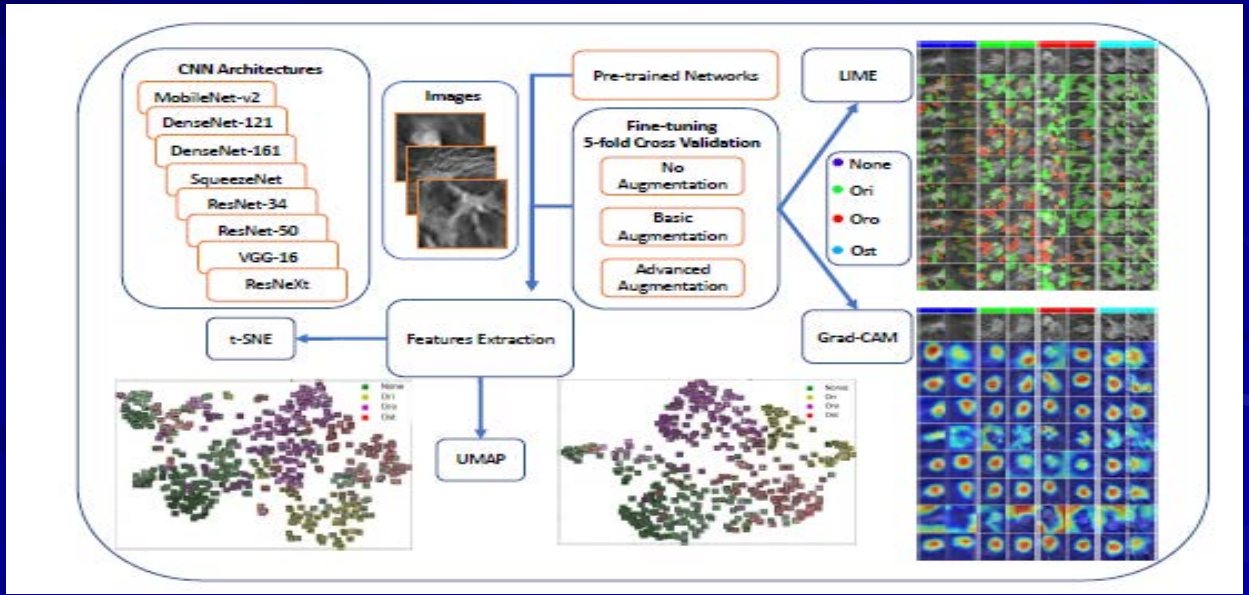
Architectural Distortion


CNN Architectures
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DenseNet-121
DenseNet-161
SqueezeNet
ResNet-34
ResNet-50
VGG-16
ResNeXt
Images
Pre-trained Networks
Fine-tuning
5-fold Cross Validation
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Advanced Augmentation
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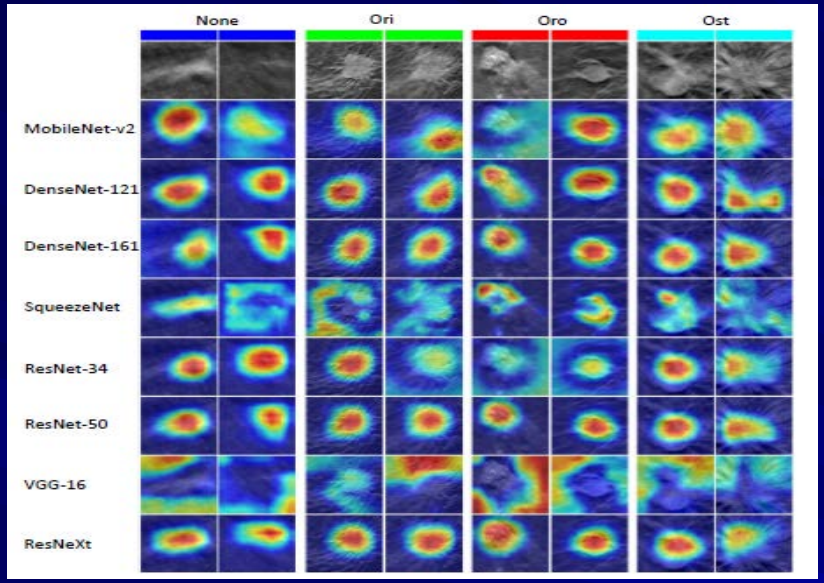
UMAP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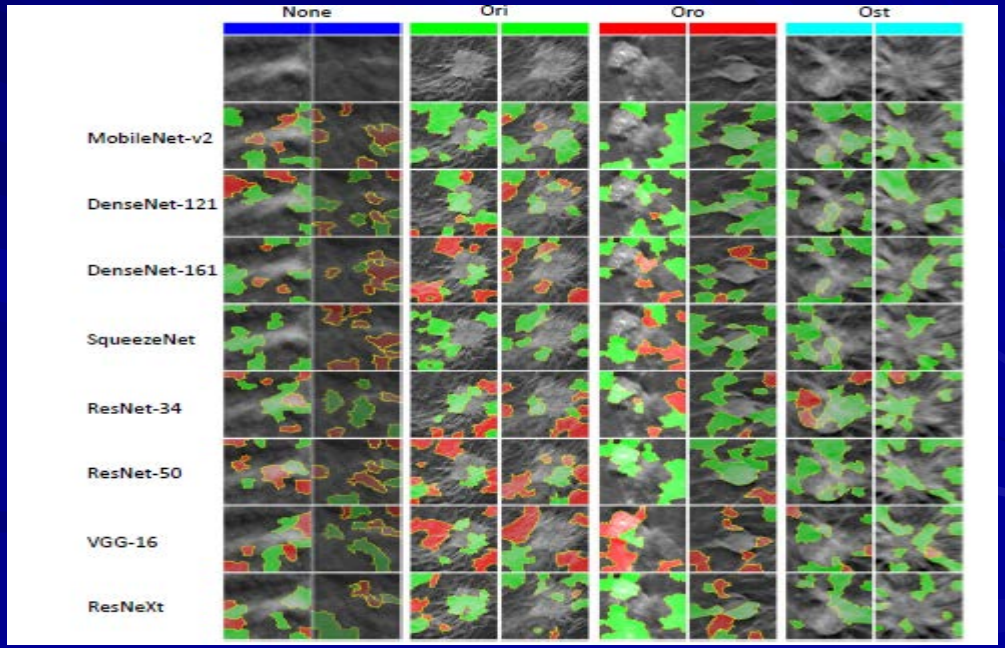
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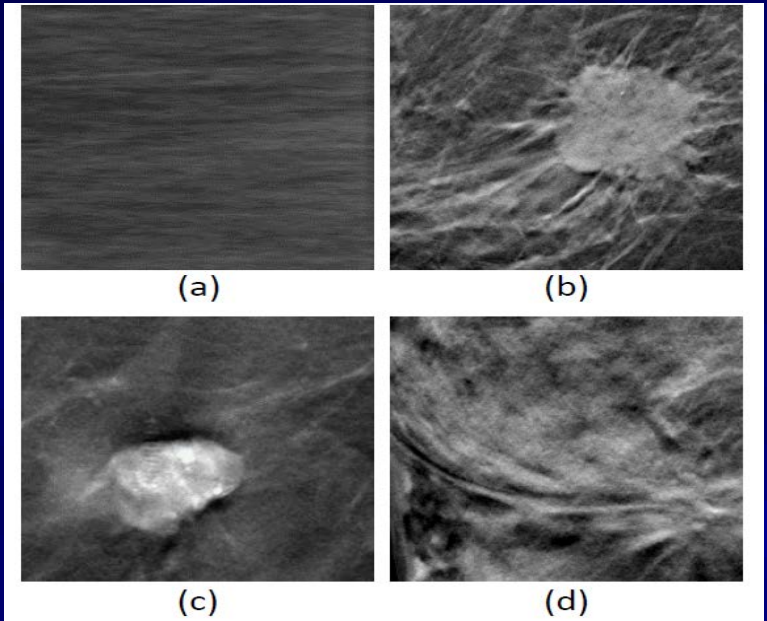
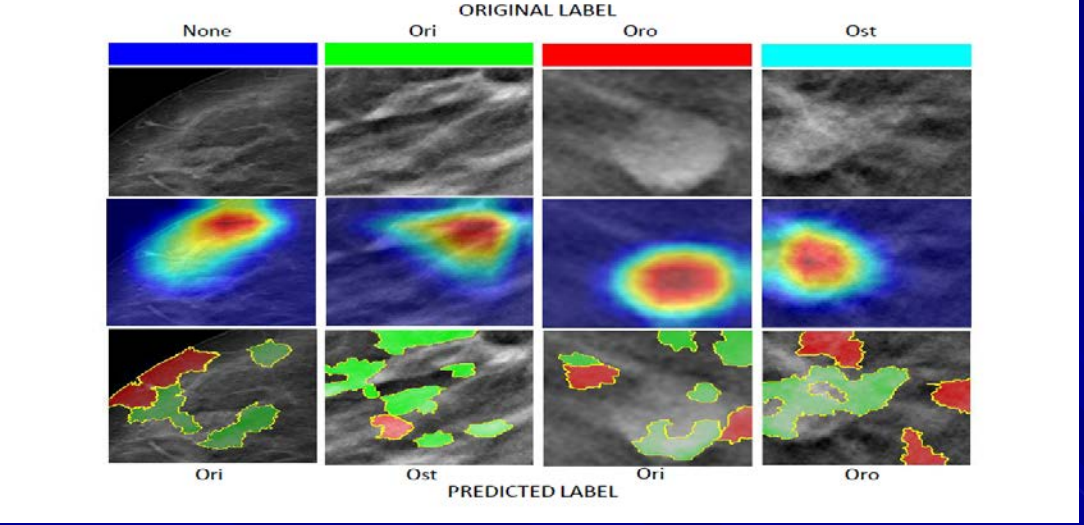
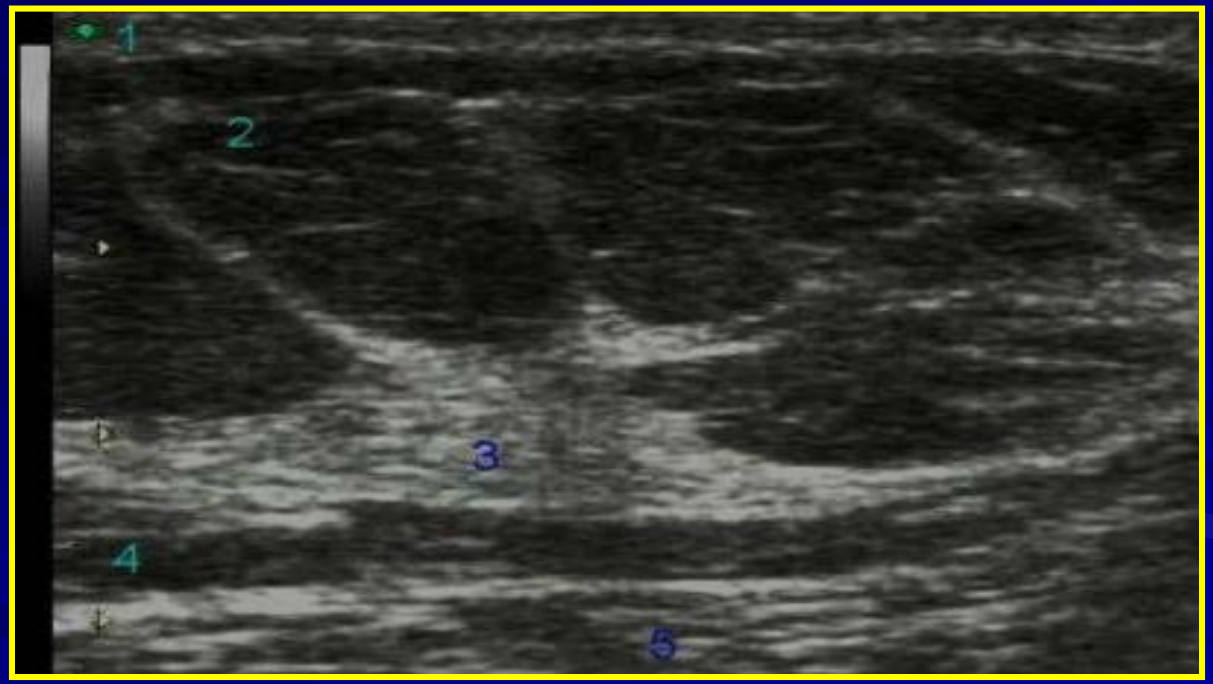



The experimental results of the classification task validate the applicability of the proposed framework by yielding the mean area under the curve of 98.2%.

*Appl. Sci.* **2022**, *12*, 6230. https://doi.org/10.3390/app12126230

# US



# US

- REPERTO US PRIVO DI CORRISPETTIVO MX-DBT
- RICERCA CORRISPETTIVO DI AD MX-DBT
- SECOND LOOK DOPO RM – NON MASSA

# US STAGING

- Utile in seni densi
- Spesso sottostima la reale estensione tumorale (circa 17%) (parte ipoecogena ed anche iperecogena periferica della lesione)
- Molte neoplasie sono lesioni “verticali”, con prevalenza dell’altezza sulla larghezza
- Presenza di cono d’ombra posteriore che oscura il margine profondo della lesione, rendendo pertanto la misurazione sull’asse maggiore più difficoltosa
- Piano assiale e sagittale

Journal of Ultrasound
https://doi.org/10.1007/s40477-020-00551-x

ORIGINAL PAPER

# Ultrasound evaluation of ductal carcinoma in situ of the breast

Marco Moschetta[1] · Angela Sardaro[2] · Adriana Nitti[2] · Michele Telegrafo[1] · Nicola Maggialetti[3] · Arnaldo Scardapane[2] · Maria Chiara Brunese[3] · Valentina Lavelli[4] · Cristina Ferrari[4]

Received: 8 October 2020 / Accepted: 10 December 2020


## Abstract

**Purpose** To assess the role of ultrasound (US) in detecting and characterizing ductal carcinoma in situ (DCIS) of the breast and to investigate the correlation between ultrasonographic and biological features of DCIS.

**Methods** In total, 171 patients (mean age 44; range 39–62) with 178 lesions were retrospectively evaluated by two independent radiologists searching for US mass or non-mass lesions. Immunohistochemistry analysis was performed to determine estrogen receptor (ER), progesterone receptor (PR), and human epidermal growth factor receptor 2 (HER2) expression. The US detection rate and pattern distribution among the lesion types were evaluated. The $\chi^2$ test was used to evaluate the correlation between the US findings and the biological factors. Statistical significance was indicated by $p$ values $< 0.05$. Inter-observer agreement was calculated by Kohen's $k$ test.

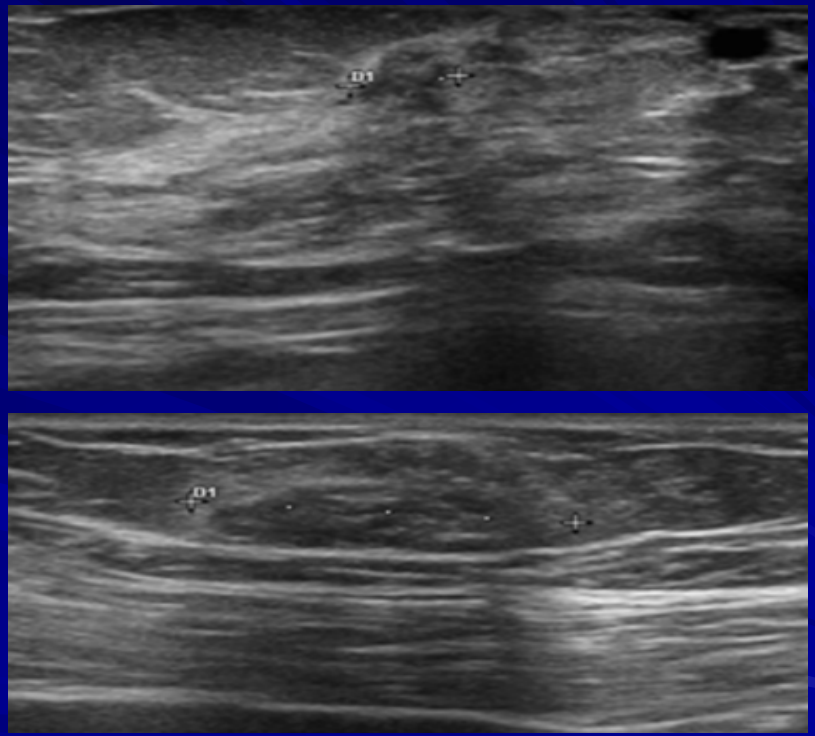
**Results** US detected 35% (63/178) of all lesions. Fifty-two (83%) lesions were classified as mass lesions, and 11 (17%) as non-mass lesions ($p < 0.0001$). Among the mass lesions, the most common shape was irregular (79%; $p < 0.0001$), with 45 (87%) lesions having indistinct margins. Hypoechogenicity was the most common echo pattern (49 cases, 94%; $p < 0.0001$). Microcalcifications were found in 23 cases (37%; $p = 0.004$) and were associated with mass lesions in 15 cases (65%) and with non-mass lesions in 8 cases (35%) ($p = 0.21$). An almost perfect inter-observer agreement ($k = 0.87$) was obtained between the two radiologists. A significant ER expression was found in mass lesions (83%; $p < 0.0001$), with no significant PR ($p = 0.89$) or HER2 expression ($p = 0.81$). Among the lesions with microcalcifications, only 7 out of 23 cases (30%) were positive for HER2 ($p = 0.09$).

**Conclusion** DCIS represents a heterogeneous pathological process with variable US appearance (mass-like, non-mass-like, or occult). The most common US finding is represented by mass-type, hypoechogenic lesions with indistinct margins. A significant ER expression exists among mass-type lesions, while microcalcifications seem not to be associated with HER2 expression.

**Keywords** Breast cancer · DCIS · US · Ultrasound

**Table 1** Ultrasonographic features of ductal carcinoma in situ (DCIS) lesions

| DCIS ultrasonographic features | Number of lesions ($n = 178$) |
|---|---|
| Lesion patterns | |
| Occult | 65% (115/178) |
| Non-occult | 35% (63/178) |
| Mass | 83% (52/63) |
| Non-mass lesions | 17%(11/63) |
| Microcalcifications | 37% (23/63) |
| Mass like | 29% (15/52) |
| Non-mass like | 72% (8/11) |



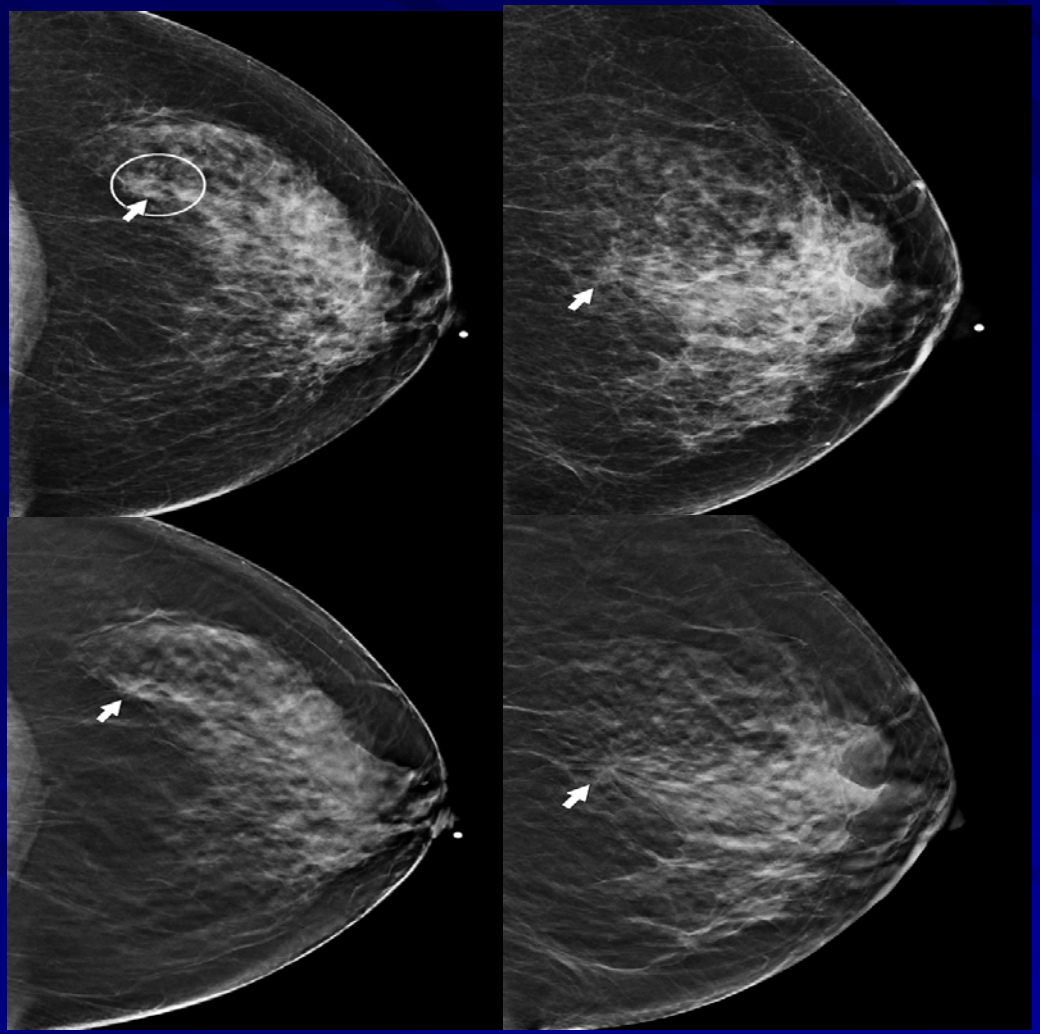
Breast Cancer (2012) 19:295–301
DOI 10.1007/s12282-012-0364-z

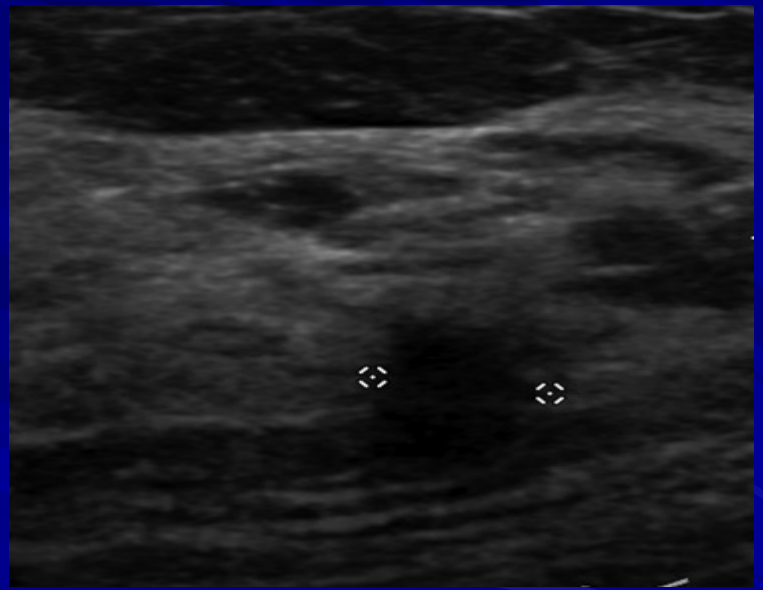
REVIEW ARTICLE

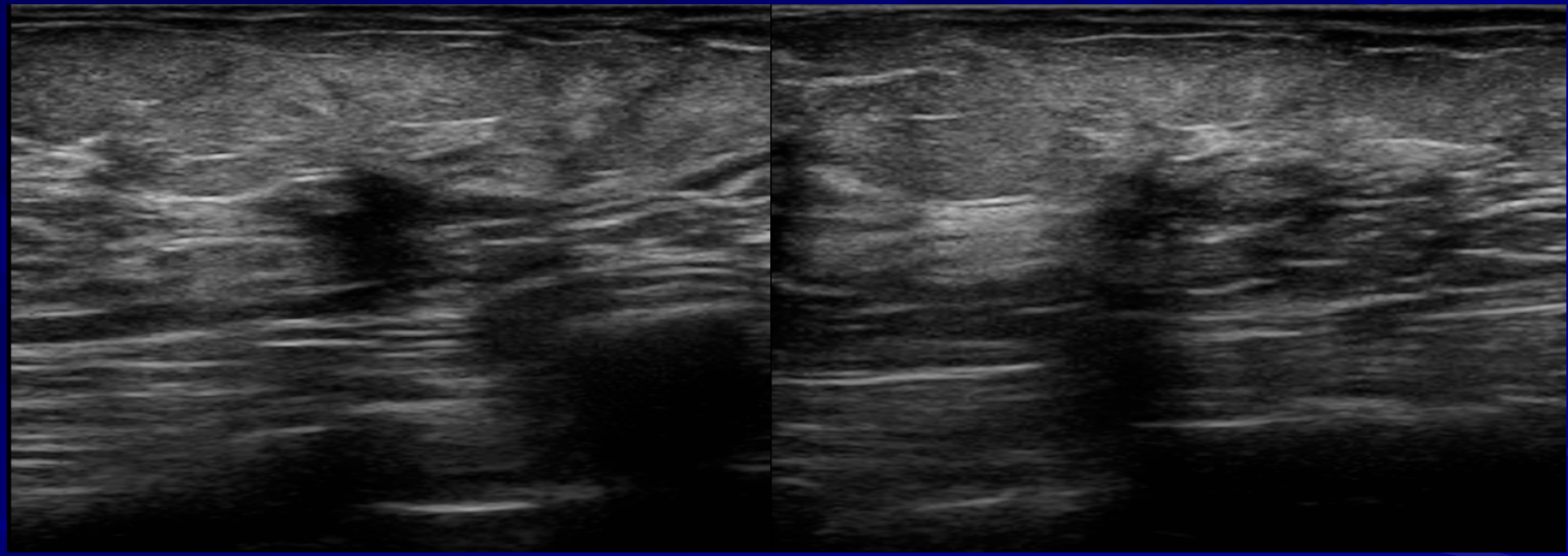
# Non-mass-like lesions on breast ultrasonography: a systematic review

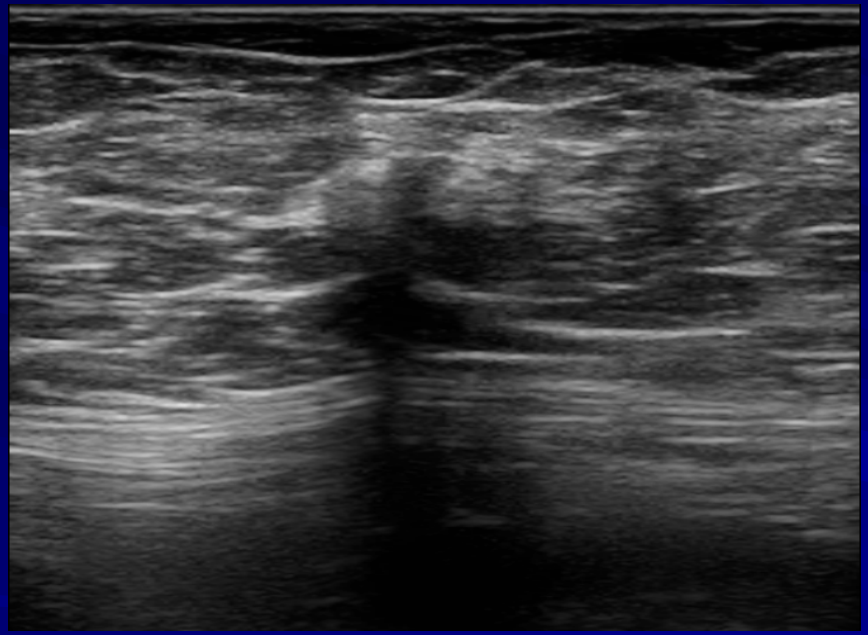
Takayoshi Uematsu

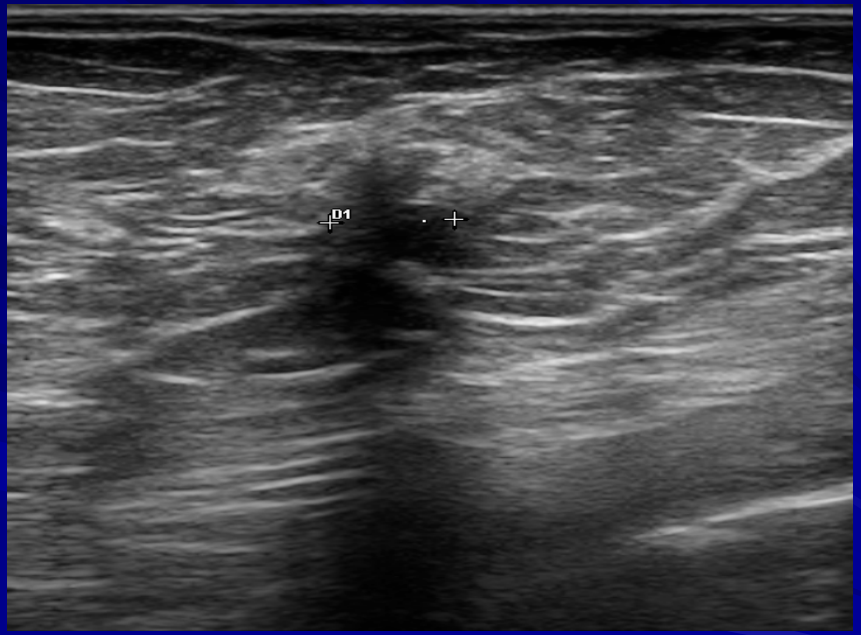
- High-resolution US allows for identification of small, clinically occult non-mass-like US findings.
- Ductal carcinoma in situ and invasive lobular carcinoma usually manifest as a non-mass-like lesion on US.
- It is useful to classify non-mass-like lesions on US in a similar manner to the classification of non-mass-like enhancement on MRI.







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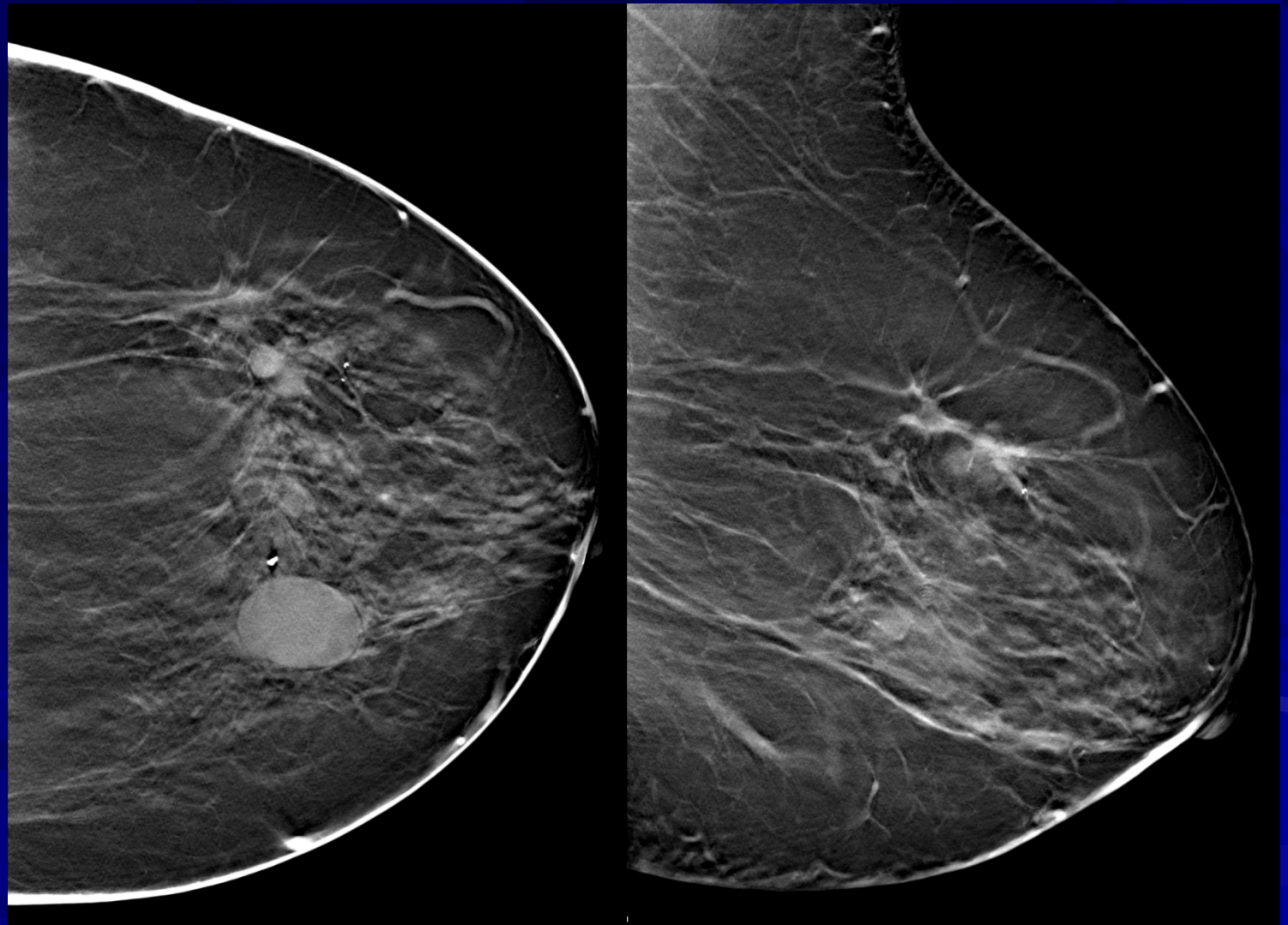
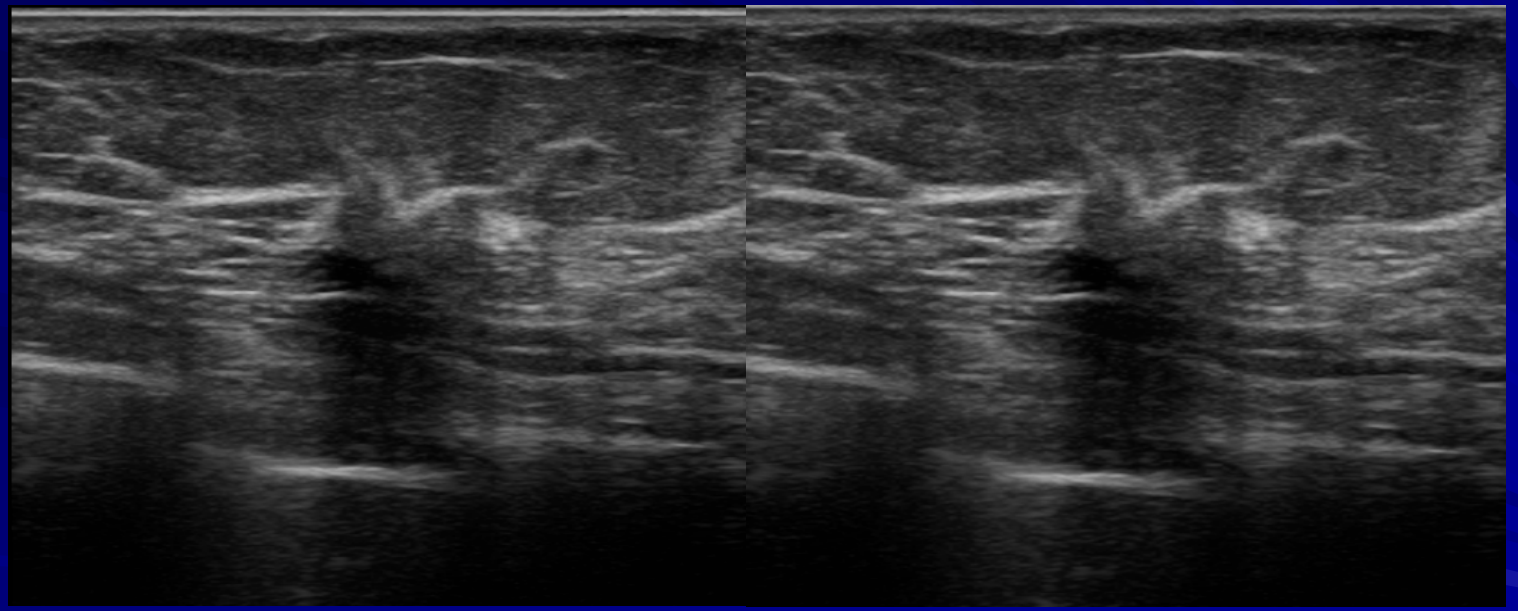
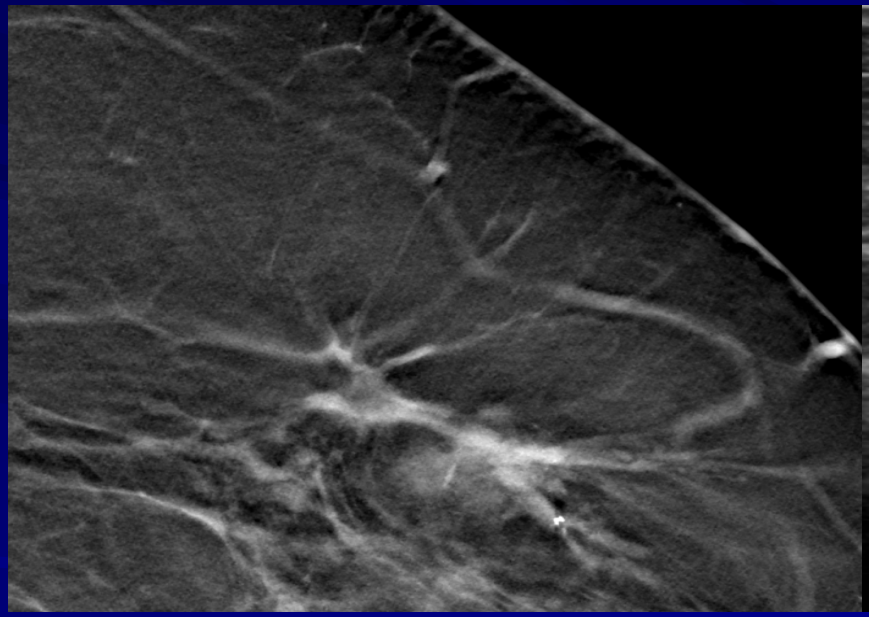
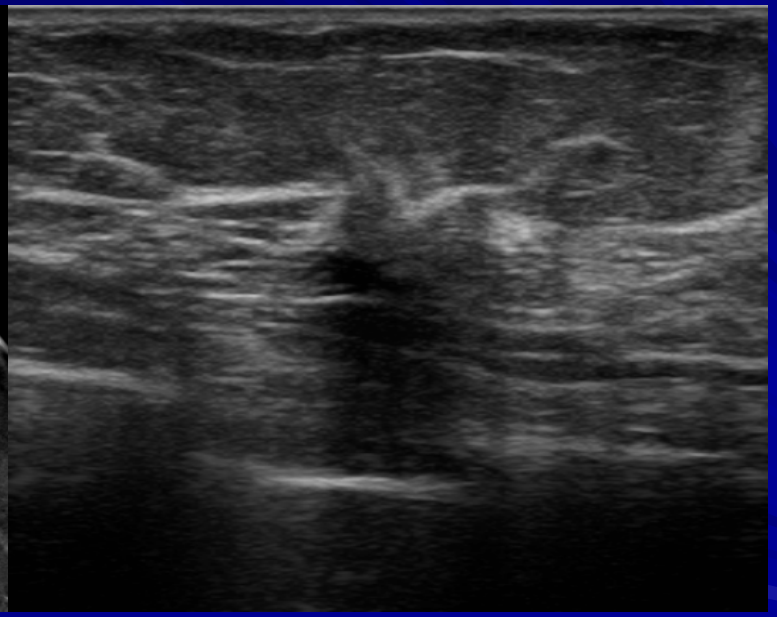
# ILC

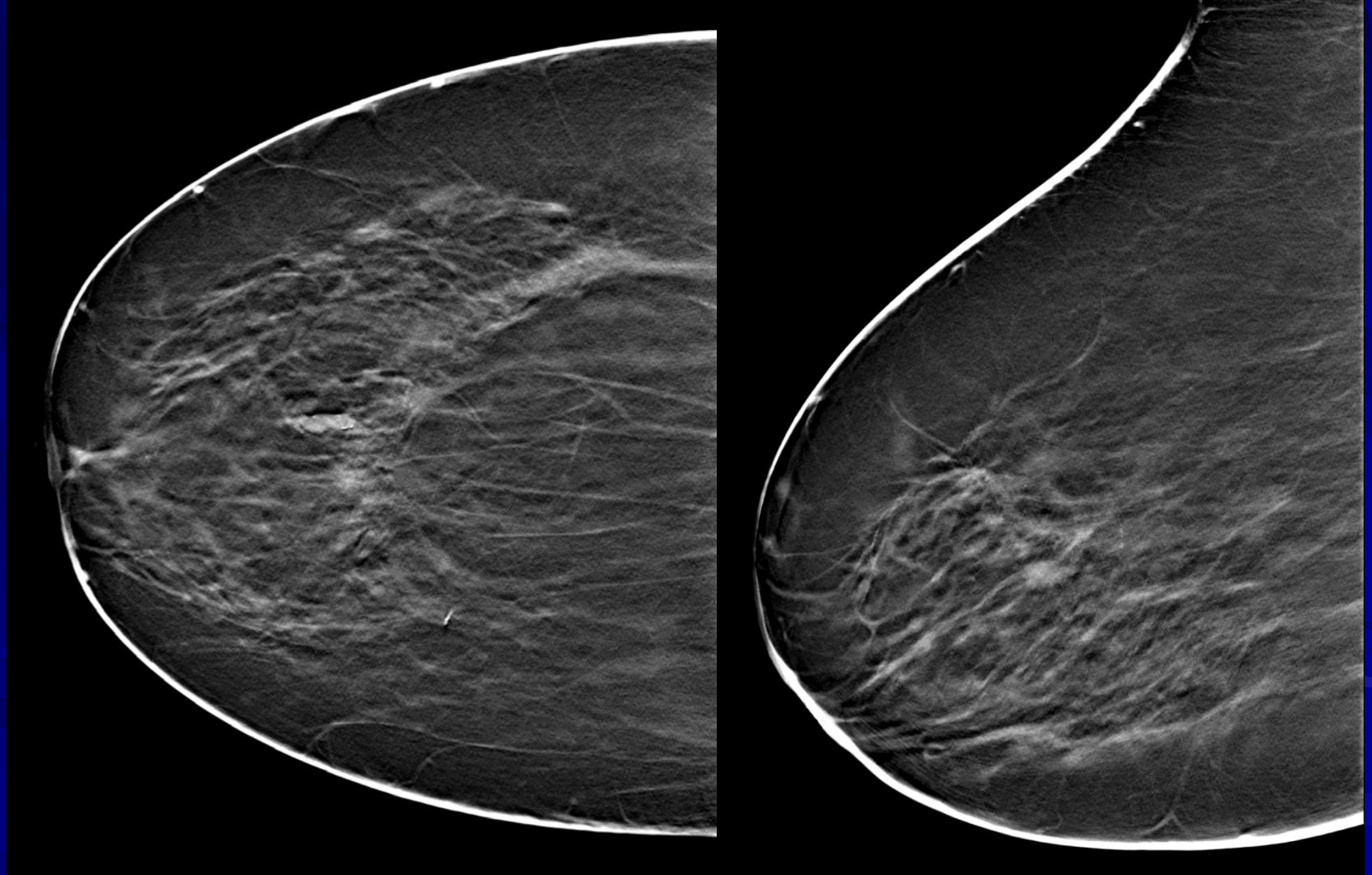
- On MRI, non-mass-like enhancement is also a common finding of ILC
- It can often also manifest as non-mass-like US findings
- ILC is composed of noncohesive cells individually dispersed or arranged in a single-file linear pattern within a fibrous stroma
- The histopathological characteristics can be reflected in the nonmass- like lesions on US and MRI

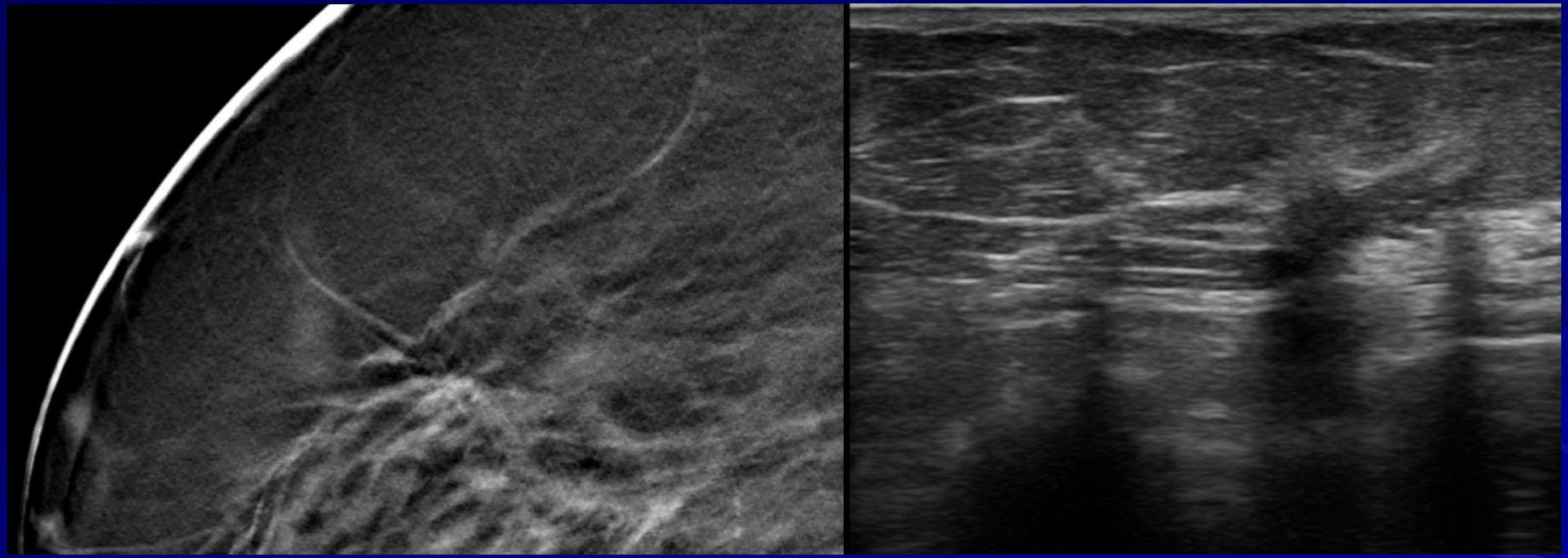


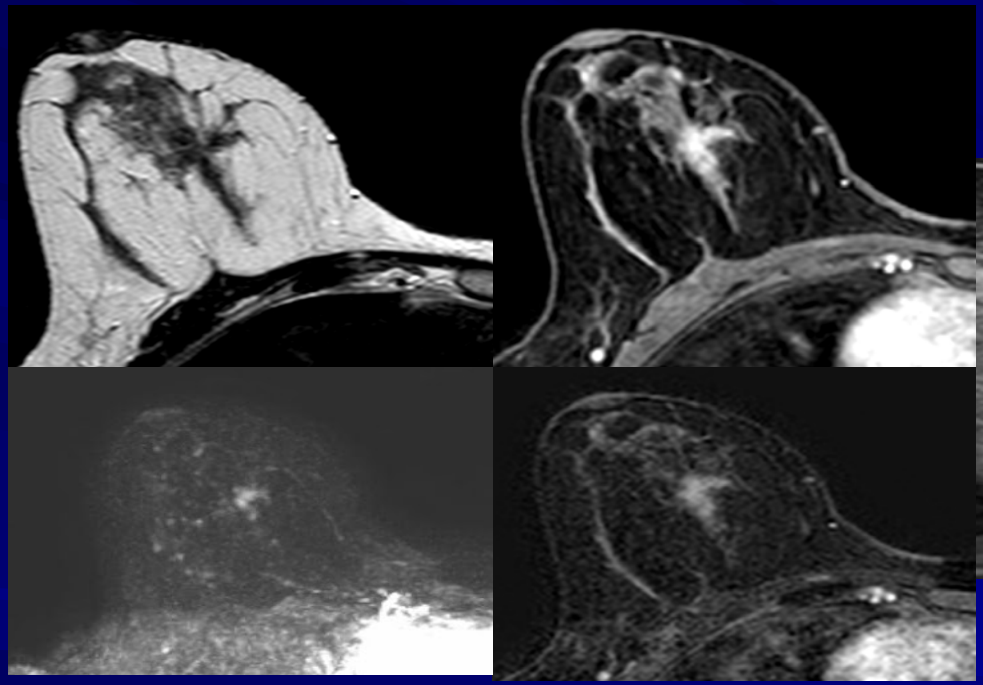


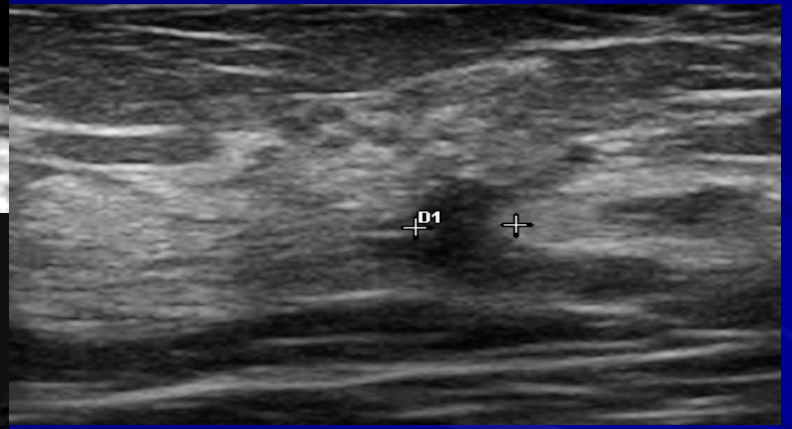








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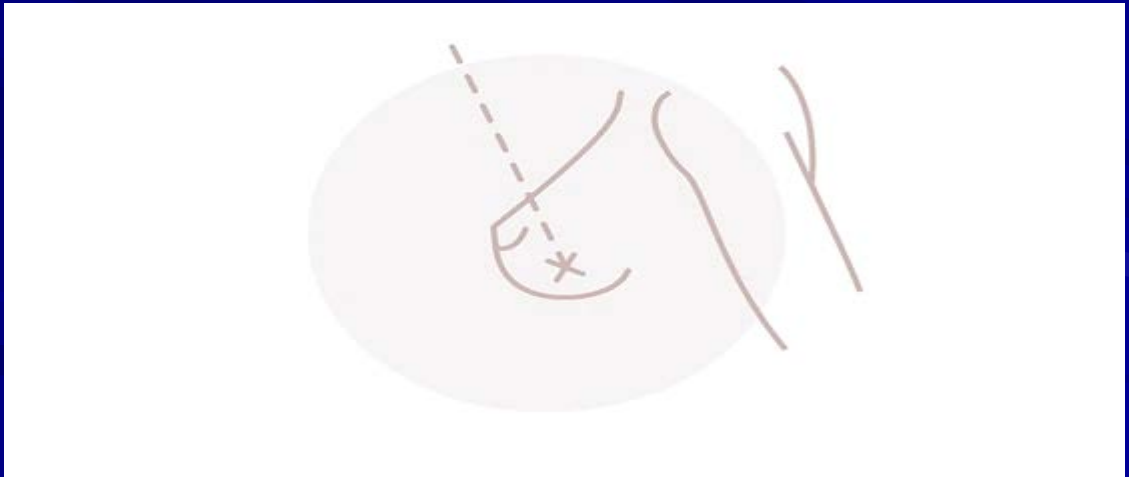
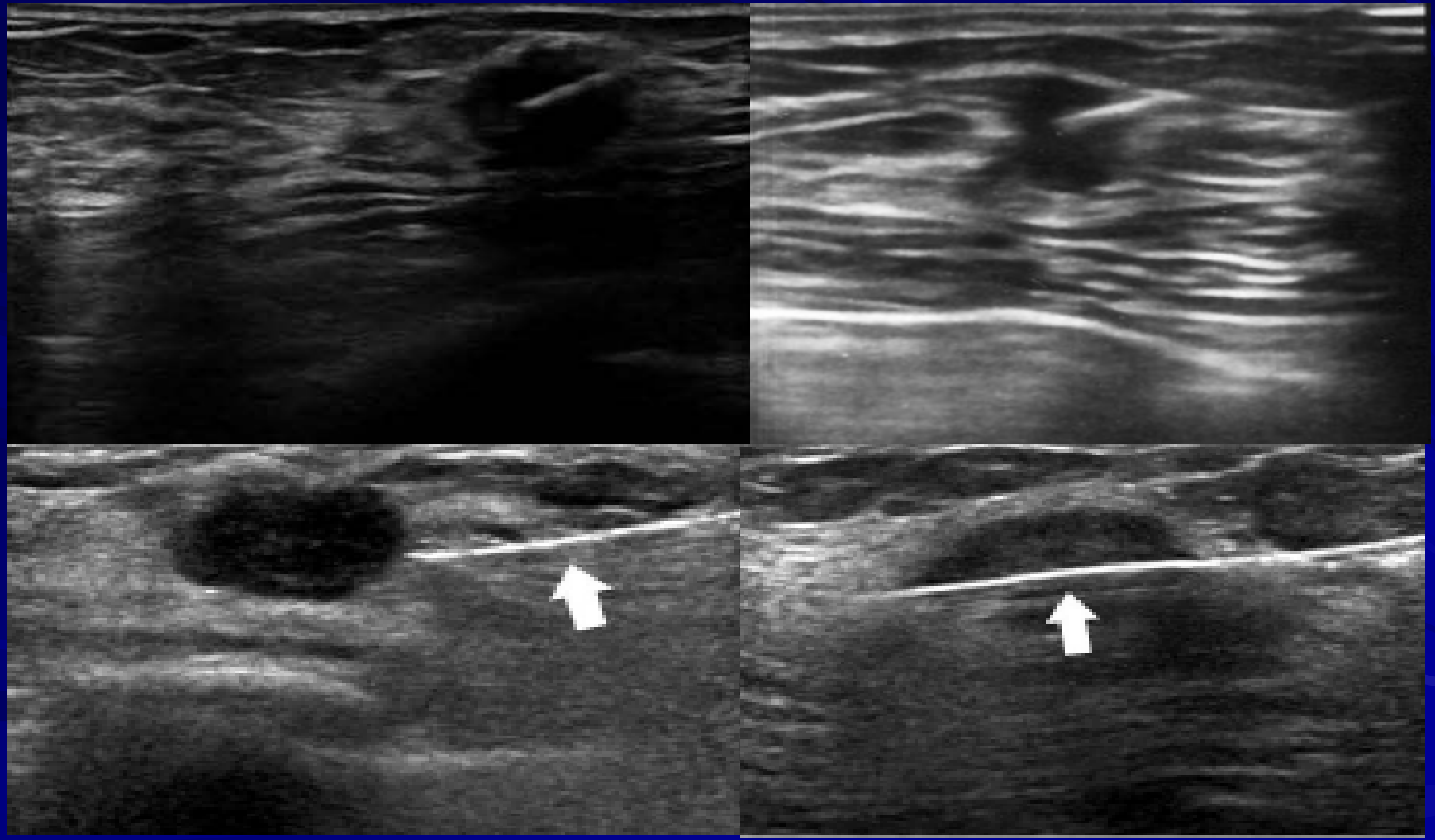
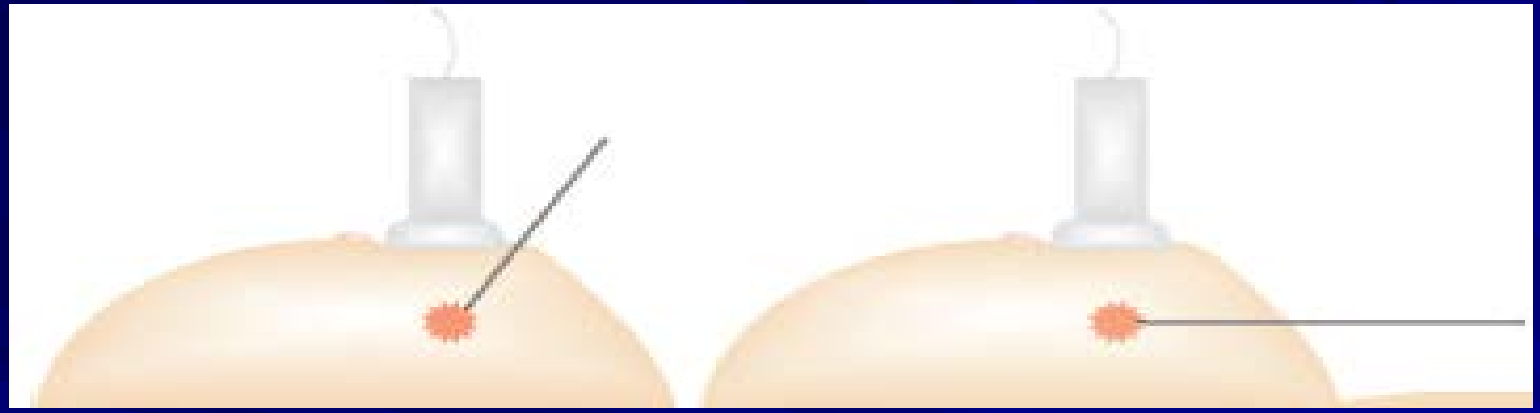
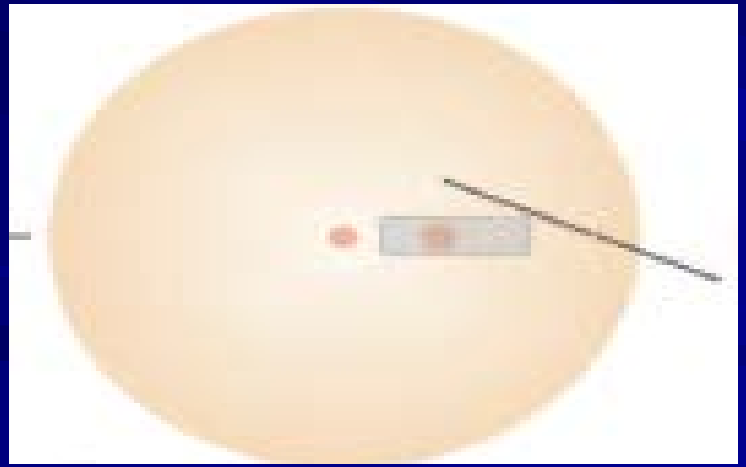
# INTERVENTIONAL

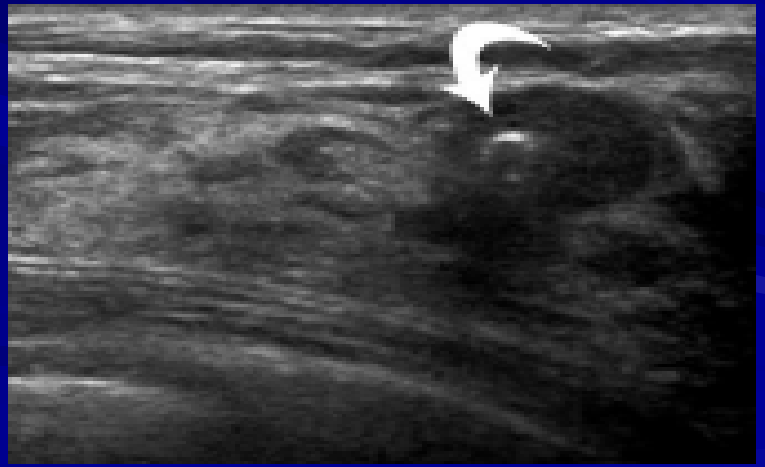
## US-CNB

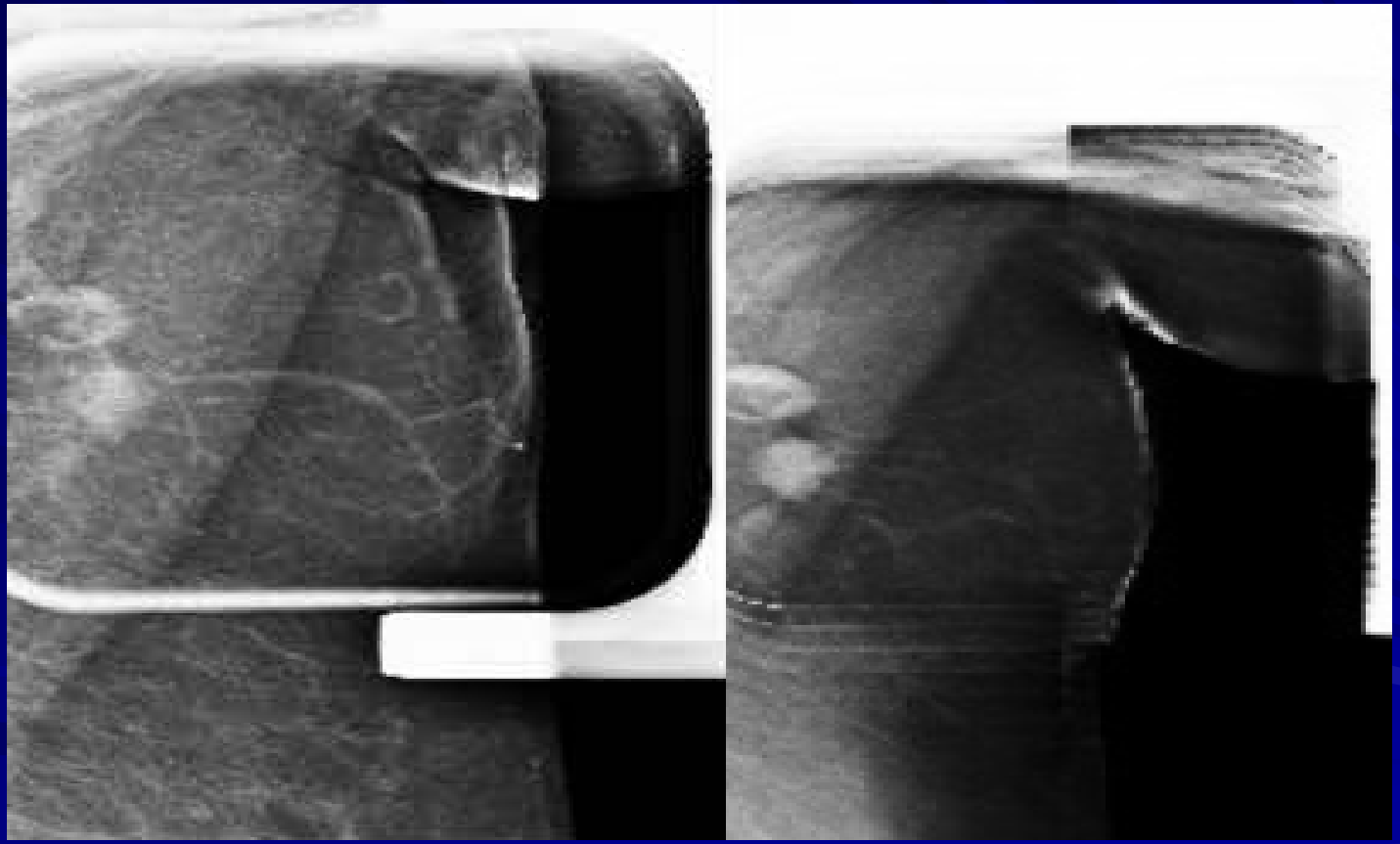












- **“La presenza di metastasi linfonodali ascellari rappresenta un fattore prognostico fondamentale nella valutazione clinica di pazienti affette da cancro mammario e condiziona l’iter terapeutico delle stesse ”**

Kleer CG, Sabel MS. Prognostic and predictive factors in breast cancer. In: , Kuerer HM, ed. *Kuerer’s breast surgical oncology.* New York, NY: McGraw-Hill, 2010; 244

- **“La biopsia del linfonodo sentinella ha sostituito la dissezione ascellare come approccio strumentale alla valutazione dell’ascella nei casi di cancro mammario precoce avendo un tasso significativamente inferiore di morbilità rispetto alla dissezione ascellare ed un basso tasso di falsi negativi”**

Lyman GH, Giuliano AE, Somerfield MR, et al.. American Society of Clinical Oncology guideline recommendations for sentinel lymph node biopsy in early-stage breast cancer. *J Clin Oncol* 2005;23(30): 7703–7720.

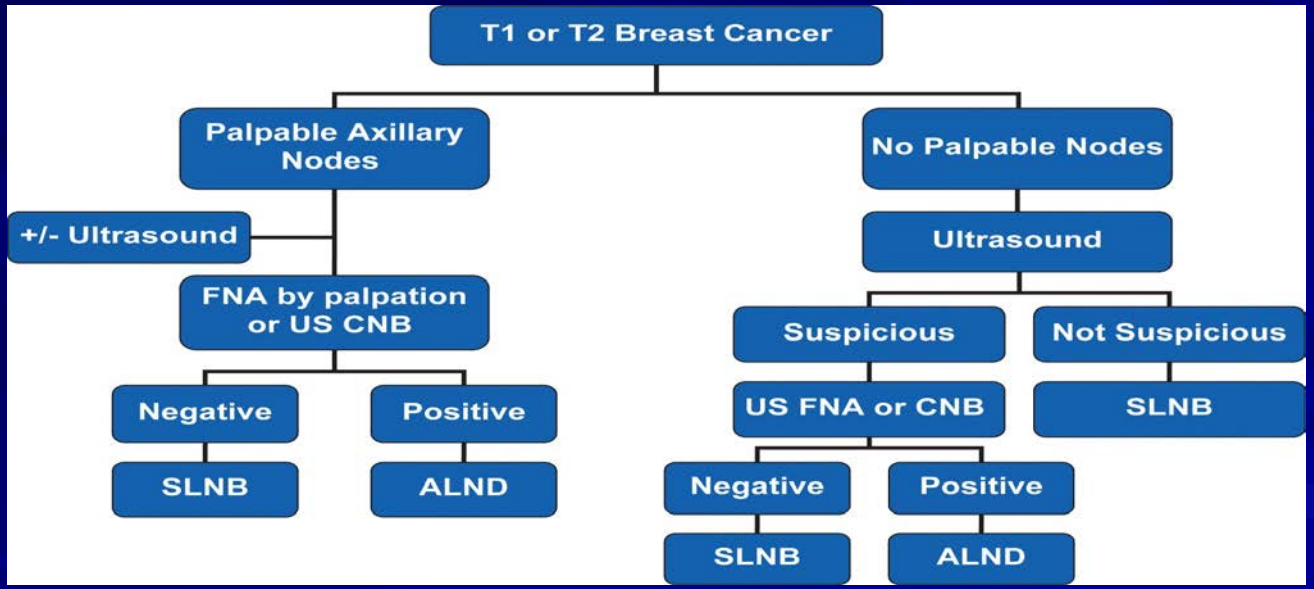
# RUOLO DELLA DIAGNOSTICA PER IMMAGINI

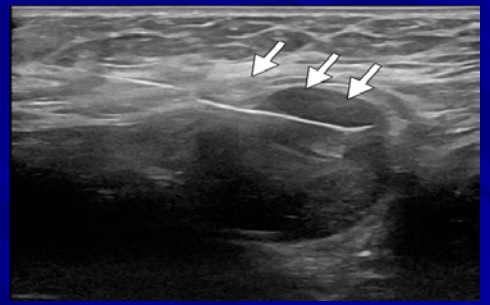
“ identificare metastasi linfonodali ascellari con un **valore predittivo positivo** sufficientemente elevato da indurre il chirurgo a procedere direttamente con la dissezione linfonodale ascellare”

# METODICHE DI IMAGING

- US
- RM
- TC
- PET-TC

# RUOLO DELLA DIAGNOSTICA PER IMMAGINI



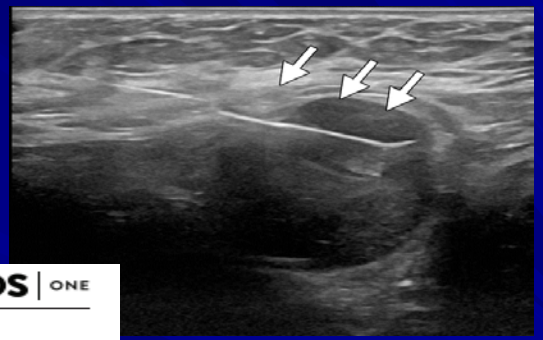
INDIVIDUAZIONE DI ***REPERTI SOSPETTI*** DA SOTTOPORRE A US-FNAC O US-CNB

# US

- METODICA DI IMAGING DI I LIVELLO CARATTERIZZATA DA **ELEVATA SPECIFICITA'**
- **GUIDA DI PROCEDURE INTERVENTISTICHE**

  **US-FNAC**

  **US-CNB**



OPEN ACCESS Freely available online

PLOS ONE

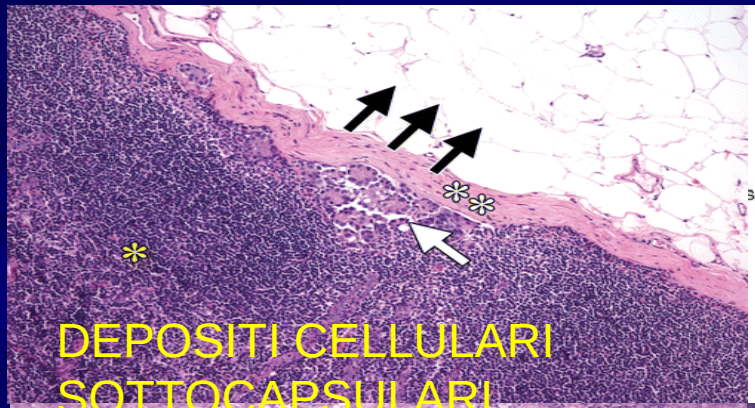
## Efficiency of a Preoperative Axillary Ultrasound and Fine-Needle Aspiration Cytology to Detect Patients with Extensive Axillary Lymph Node Involvement

Isabella Castellano[1]*, Cristina Deambrogio[1], Francesca Muscarà[1], Luigi Chiusa[1], Giovanna Mariscotti[2], Riccardo Bussone[3], Guglielmo Gazzetta[3], Luigia Macrì[1], Paola Cassoni[1], Anna Sapino[1]

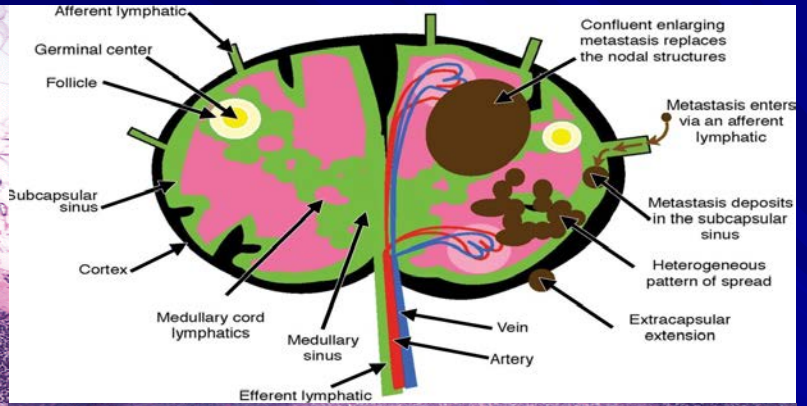
1 Department of Medical Sciences, University of Turin, Turin, Italy, 2 Istituto di Radiologia Diagnostica ed Interventistica, University of Turin, Città della Salute e della Scienza, Molinette Hospital, Turin, Italy, 3 Breast Surgery Department, Città della Salute e della Scienza, Sant'Anna Hospital, Turin, Italy

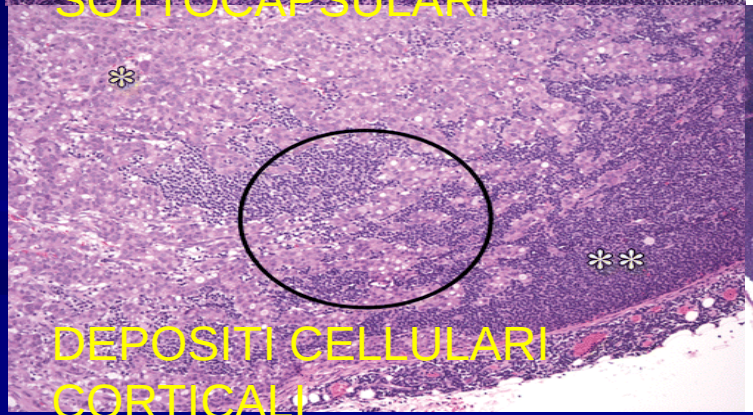
**"Positive US-guided FNA cytology performed on a single lymph node could be a marker for the possible involvement of >1 axillary lymph nodes, particularly in large tumours, and thus reliably leads to onestep ALND"**

# REPERTI PATOLOGICI

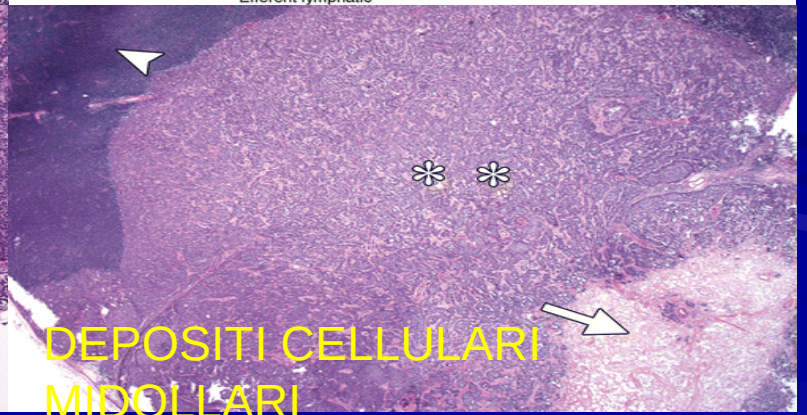


DEPOSITI CELLULARI SOTTOCAPSULARI



DEPOSITI CELLULARI CORTICALI



DEPOSITI CELLULARI MIDOLLARI

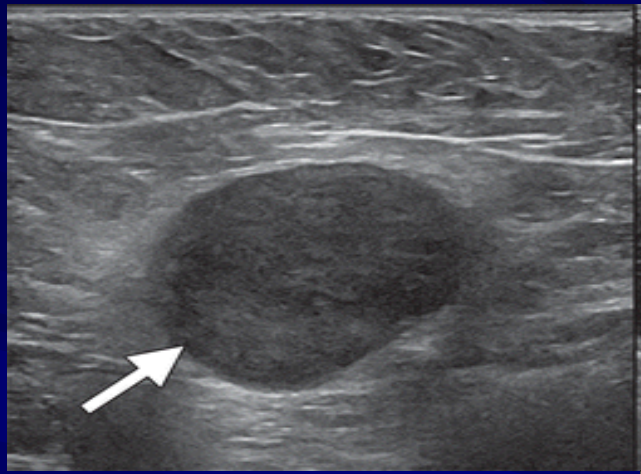
# REPERTI ECOGRAFICI

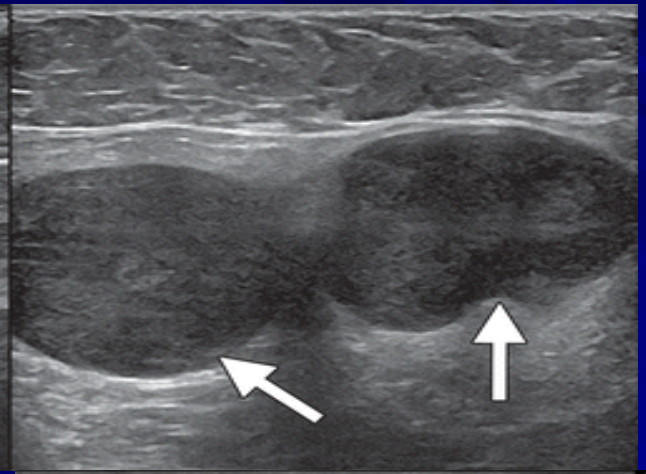
## CRITERI MORFOLOGICI

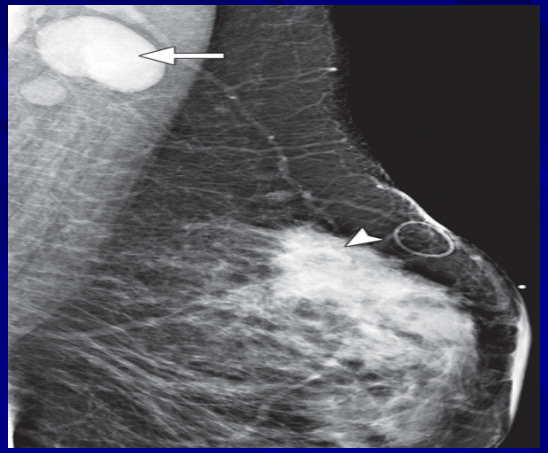
- ISPESSIMENTO DIFFUSO (> 3 MM) DELLA CORTICALE LINFONODALE
- ISPESSIMENTO FOCALE DELLA CORTICALE CON ASSOCIATO FLUSSO EMATICO CORTICALE NON ILARE (NHBF)
- LINFONODO A MORFOLOGIA ROTONDEGGIANTE ED ECOSTRUTTURA DIFFUSAMENTE IPOECOGENA CON PERDITA DEL TESSUTO ADIPOSO ILARE E CON ASSOCIATO FLUSSO EMATICO CORTICALE NON ILARE (NHBF)
- FORMAZIONE NODULARE DISOMOGENEA ED A MARGINI IRREGOLARI CON NHBF NEL CONTESTO DEL LINFONODO

### CRITERIO DIMENSIONALE

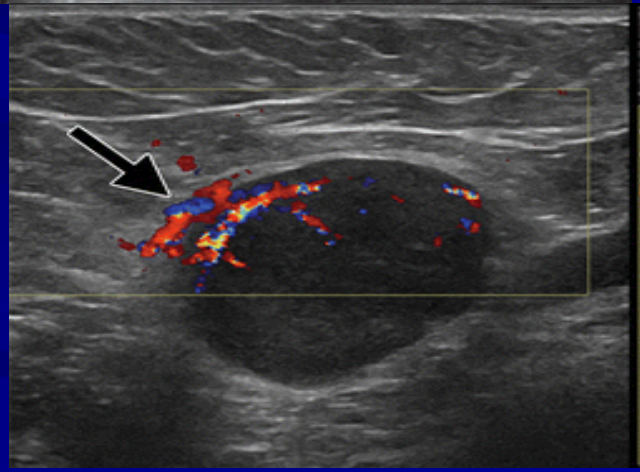
- COME SINGOLO REPERTO PRESENTA BASSA ACCURATEZZA

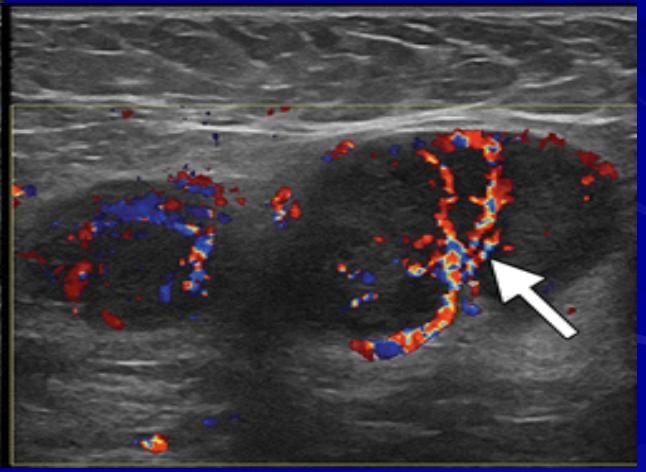


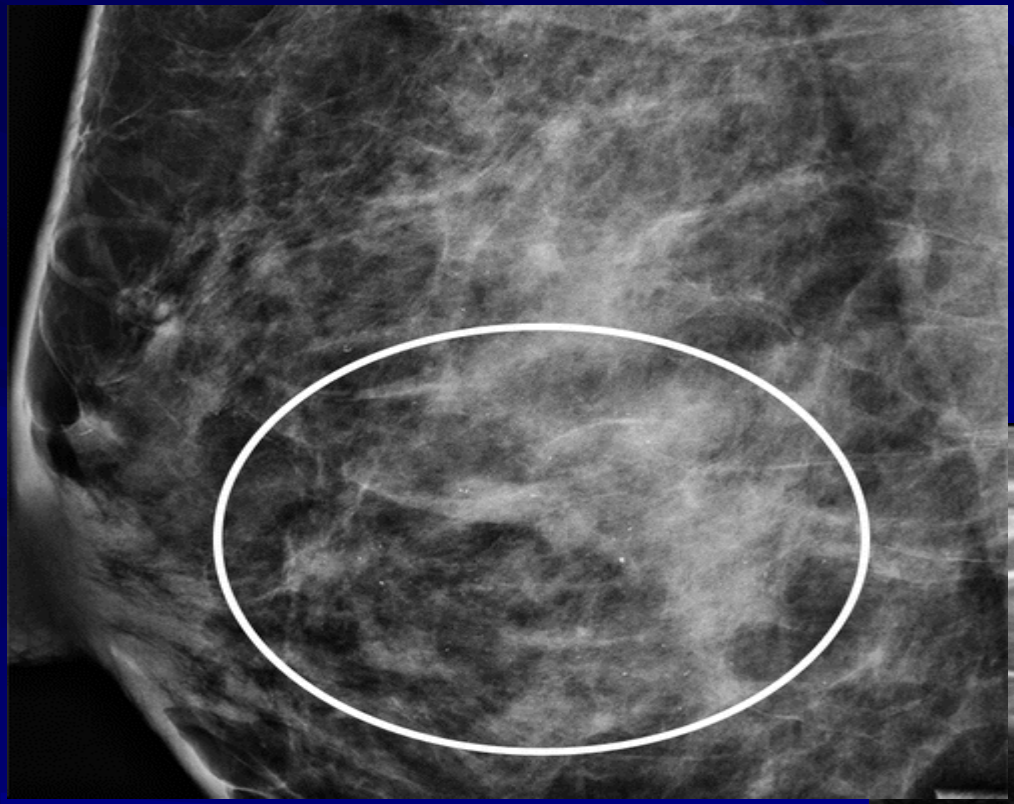




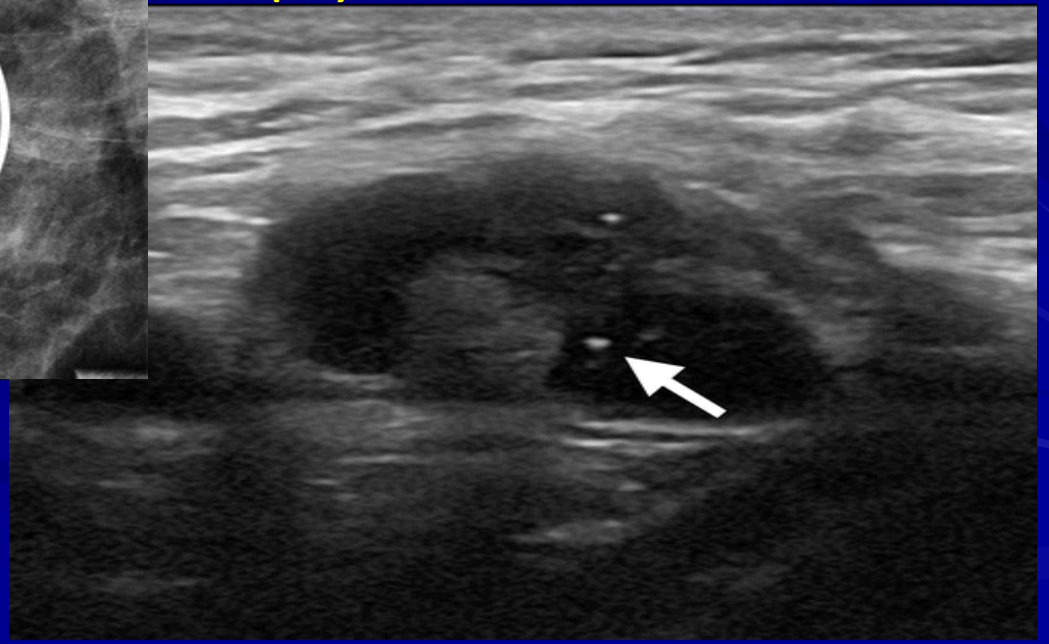
- *MORFOLOGIA ROTONDEGGIANTE*
- *ECOSTRUTTURA DIFFUSAMENTE IPOECOGENA*
- *PERDITA IPERECOGENICITA' ILARE*

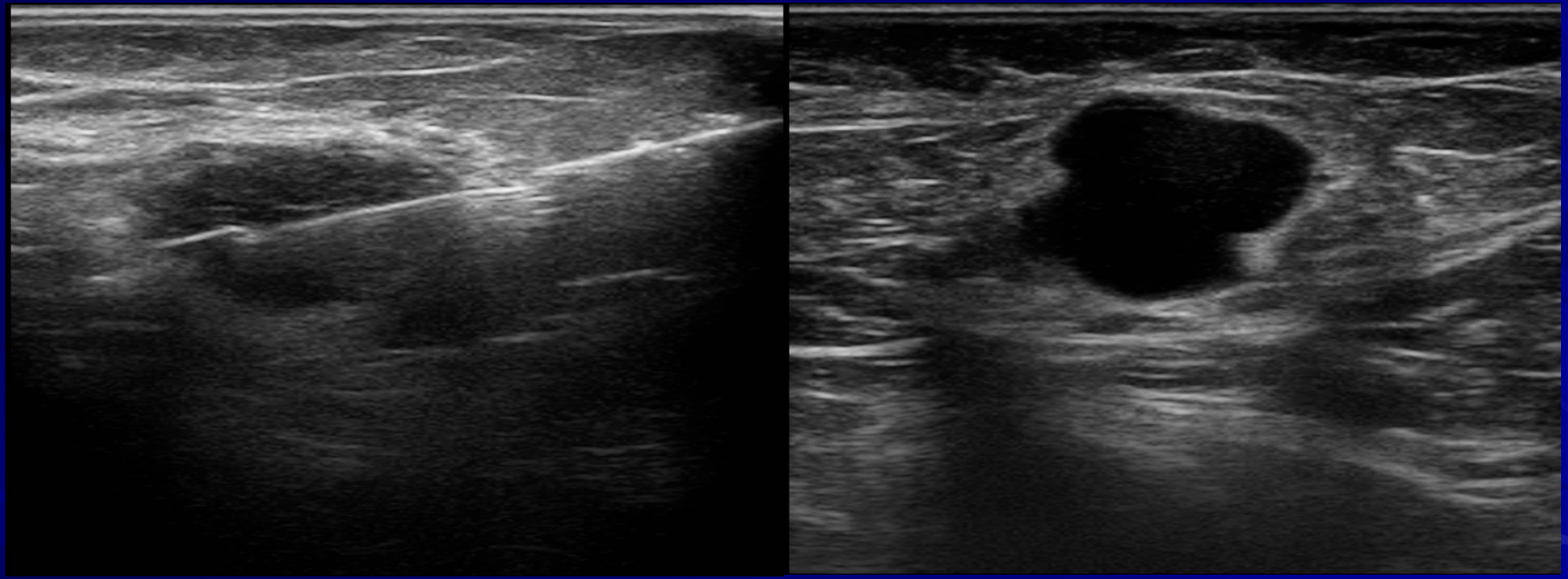






*MICROCALCIFICAZIONI DELLA LESIONE PRIMITIVA (MX) E NEL CONTESTO DI LINFOADENOPATIA ASCELLARE (US)*





# POTENZIALITA’ US

- ELASTOGRAFIA
- DOPPLER
- ABUS

# MULTIPARAMETRIC US

"Apart from morphologic imaging with standard B-mode, several functional US-based modalities have been assessed, including elastography, Doppler, and contrast-enhanced US (CEUS). These sonographic modalities provide not only functional information about breast tumors, but also offer a multitude of quantitative parameters that can be used as imaging biomarkers.

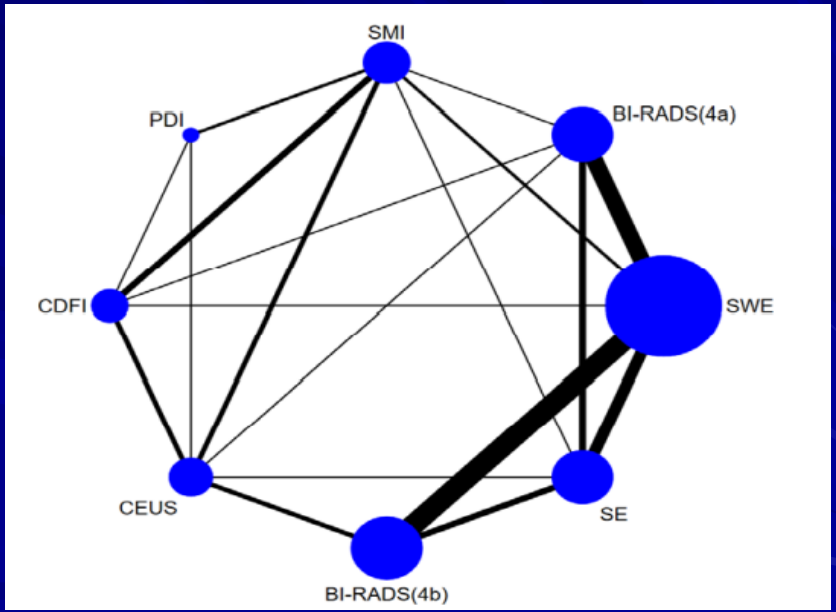
Several studies have shown promising results for each US parameter in providing valuable diagnostic, prognostic, and predictive imaging biomarkers"

- *Saracco A, Szabo BK, Aspelin P, et al. Differentiation between benign and malignant breast tumors using kinetic features of real-time harmonic contrast-enhanced ultrasound. Acta Radiol. 2012;53:382–8.*

- *“Neovascularization and microvessel density are closely related to the degree of malignancy, invasiveness, recurrence, metastasis and the prognosis of tumor patients”*

Lugano R et al. Tumor angiogenesis: causes, consequences, challenges and opportunities. Cell Mol Life Sci. 2020;77:1745–70.

- ✓ POWER DOPPLER IMAGING(PDI)
- ✓ COLOR DOPPLER FLOW IMAGING (CDFI)
- ✓ **SUPERB MICROVASCULAR IMAGING (SMI)**
- ✓ **CONTRAST-ENHANCEDULTRASOUND (CEUS)**



# CEUS
# CONTRAST ENHANCED US

- Contrast-enhanced ultrasound (CEUS) imaging with contrast agents has created a significant opportunity for visualization of lesion microcirculation

- **QUALITATIVE ASSESSMENT (ENHANCEMENT PATTERN)**

- **QUANTITATIVE ANALYSIS (TIME–INTENSITY CURVES)**

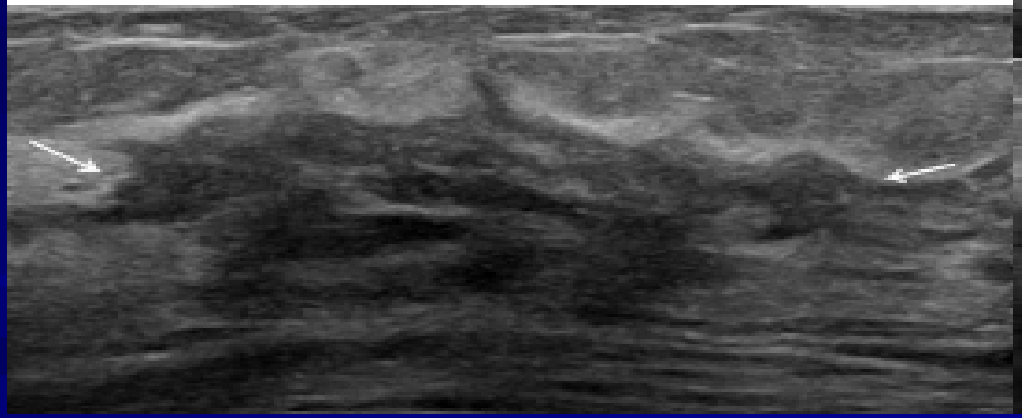
Eur Radiol
DOI 10.1007/s00330-015-4201-6

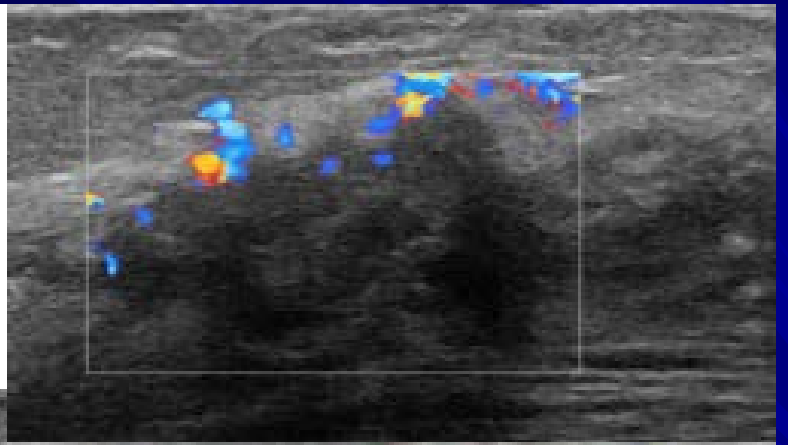
BREAST

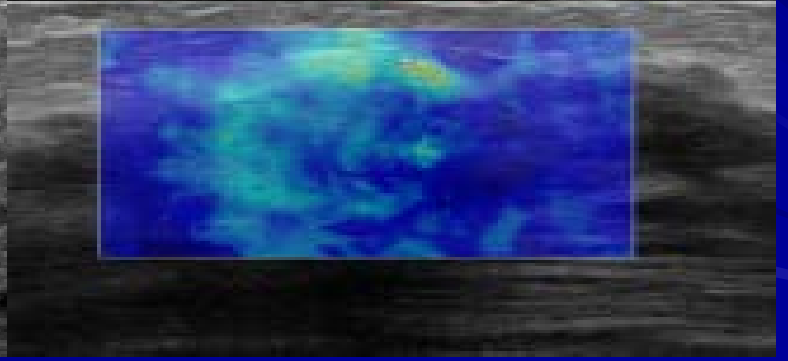
# Additional diagnostic value of shear-wave elastography and color Doppler US for evaluation of breast non-mass lesions detected at B-mode US

Ji Soo Choi[1] · Boo-Kyung Han[1] · Eun Young Ko[1] · Eun Sook Ko[1] · Jung Hee Shin[1] · Ga Ram Kim[1]

Received: 8 September 2015 / Revised: 8 December 2015 / Accepted: 30 December 2015

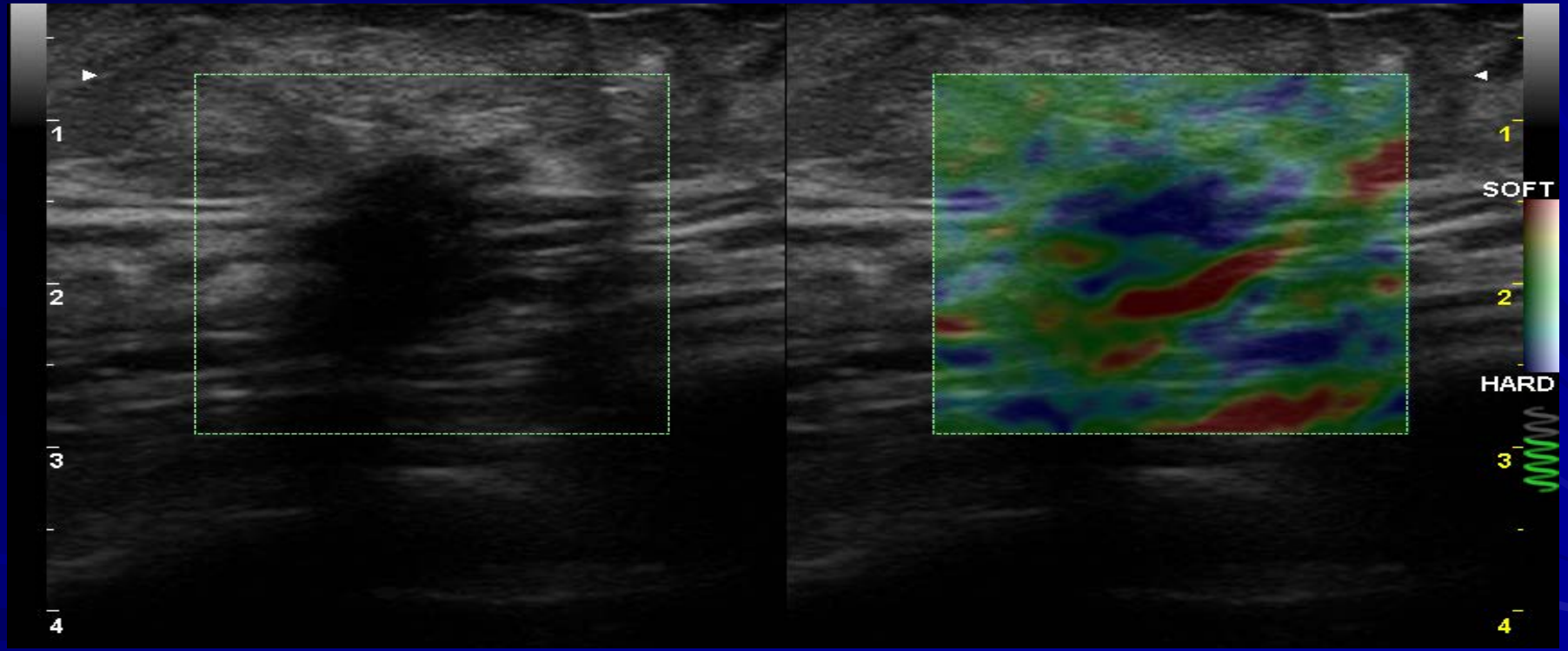




| Parameter | Sensitivity | *P* | Specificity | *P* |
|---|---|---|---|---|
| B-mode US | 100 (74/74) | – | 23.8 (10/42) | – |
| B-mode US and SWE* | 97.3 (72/74) | 0.999 | 90.5 (38/42) | <0.001 |
| B-mode US and Doppler US† | 98.6 (73/74) | 0.999 | 71.4 (30/42) | <0.001 |
| B-mode US, SWE and Doppler US‡ | 100 (74/74) | 0.999 | 69.0 (29/42) | <0.001 |

**Table 2** Diagnostic performances of B-mode US, SWE and Doppler US for differentiating benign and malignant non-mass lesions

| Parameter | AUC | Sensitivity | Specificity | Accuracy | PPV | NPV |
|---|---|---|---|---|---|---|
| B-mode US | | | | | | |
| BI-RADS category ≥4a | 0.849 | 100 (74/74) | 23.8 (10/42) | 72.4 (84/116) | 69.8 (74/106) | 100 (10/10) |
| SWE | | | | | | |
| $E_{mean}$ >85.1 kPa* | 0.924 | 78.4 (58/74) | 95.2 (40/42) | 84.5 (98/116) | 96.7 (58/60) | 71.4 (40/56) |
| $E_{max}$ >92.5 kPa* | 0.921 | 78.4 (58/74) | 92.9 (39/42) | 83.6 (97/116) | 95.1 (58/61) | 70.9 (39/55) |
| Stiff colour | 0.913 | 70.3 (52/74) | 95.2 (40/42) | 79.3 (92/116) | 96.3 (52/54) | 64.5 (40/62) |
| Doppler US | | | | | | |
| High vascularity | 0.774 | 73.0 (54/74) | 66.7 (28/42) | 70.7 (82/116) | 79.4 (54/68) | 58.3 (38/48) |
| Combination of SWE and Doppler US | | | | | | |
| $E_{mean}$ >85.1 kPa or high vascularity | 0.801 | 95.9 (71/74) | 64.3 (27/42) | 84.5 (98/116) | 82.6 (71/86) | 90.0 (27/30) |


1
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HARD

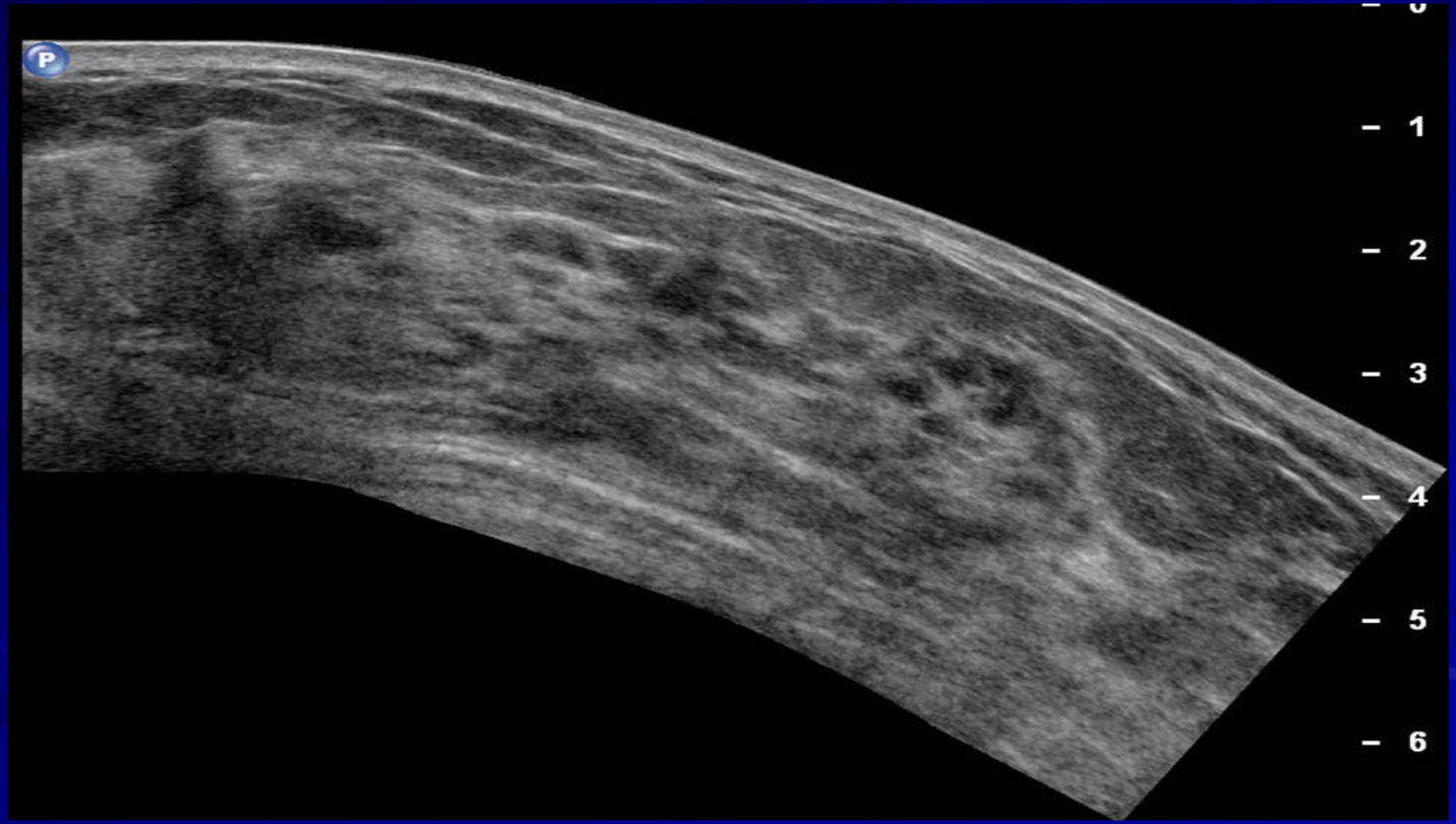
Eur Radiol (2018) 28:592–601
DOI 10.1007/s00330-017-5011-9

BREAST

# The performance of 3D ABUS versus HHUS in the visualisation and BI-RADS characterisation of breast lesions in a large cohort of 1,886 women

Athina Vourtsis[1] · Aspasia Kachulis[1]

*Conclusions* ABUS could be successfully used in the visualisation and characterisation of breast lesions. ABUS seemed to outperform HHUS in the detection of architectural distortion on the coronal plane and can supplement mammography in the detection of non-calcified carcinomas in women with dense breasts.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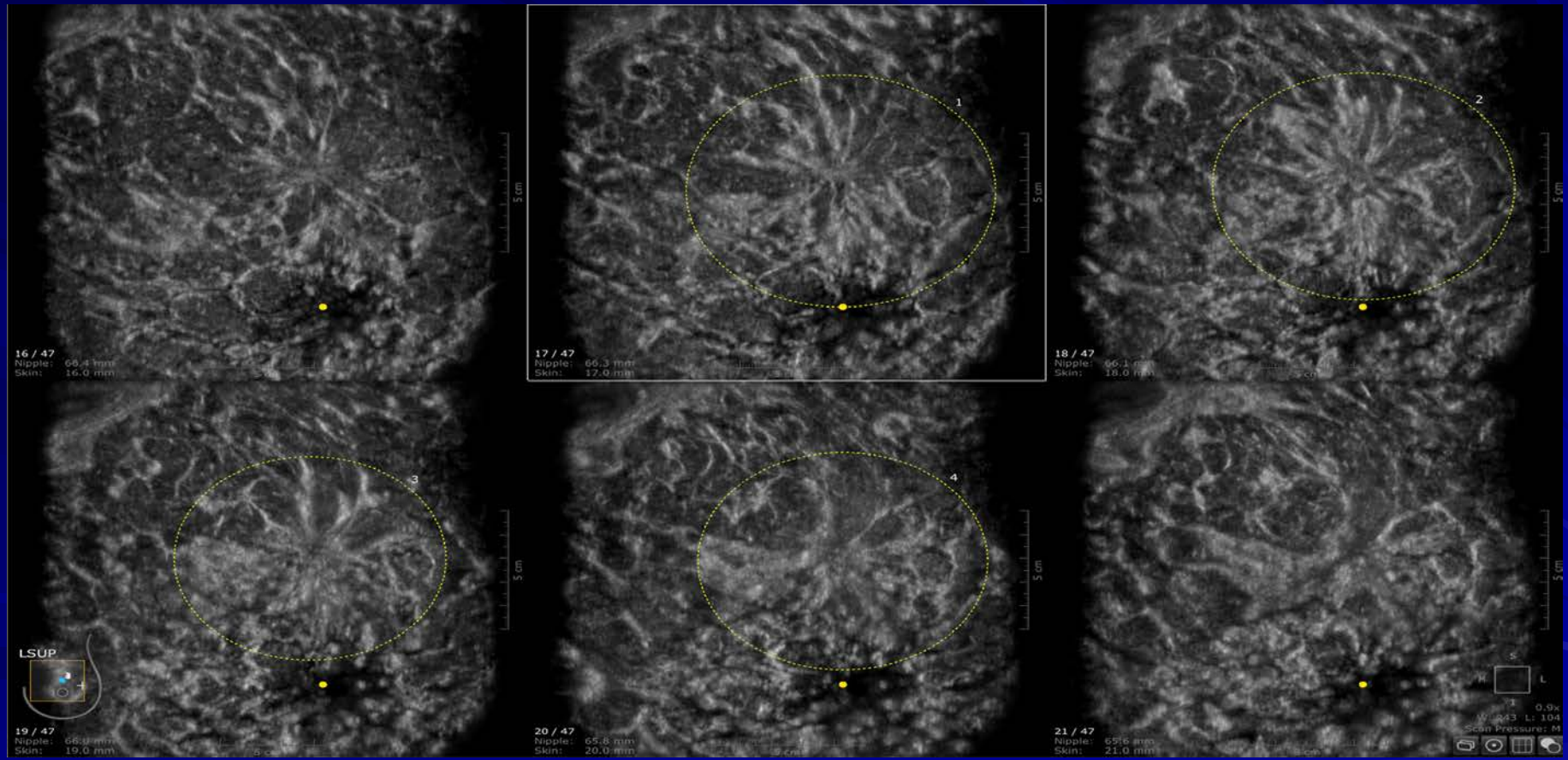
16 / 47
Nipple: 66.4 mm
Skin: 16.0 mm
17 / 47
Nipple: 66.3 mm
Skin: 17.0 mm
1
18 / 47
Nipple: 66.1 mm
Skin: 18.0 mm
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3
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LSUP
19 / 47
Nipple: 66.0 mm
Skin: 19.0 mm
20 / 47
Nipple: 65.8 mm
Skin: 20.0 mm
21 / 47
Nipple: 65.6 mm
Skin: 21.0 mm
5 cm

# Automated Breast Ultrasonography (ABUS) in the Screening and Diagnostic Setting: Indications and Practical Use

Rossella Rella, MD, Paolo Belli, MD, Michela Giuliani, MD, Enida Bufi, MD, Giorgio Carlino, MD, Pierluigi Rinaldi, MD, Riccardo Manfredi, MD

**Abbreviations and Acronyms**

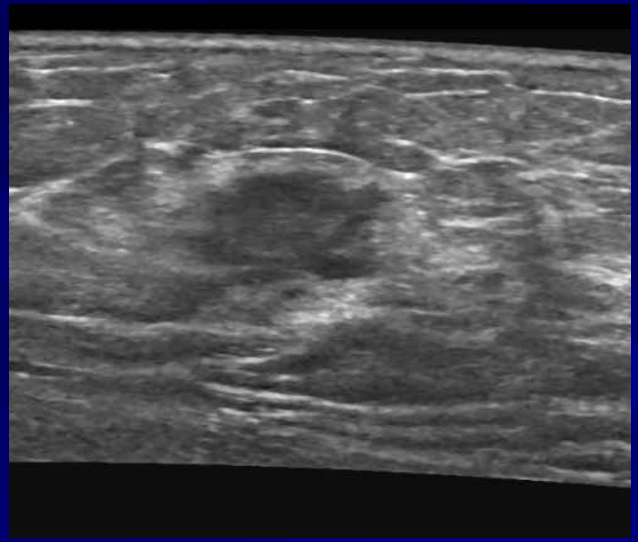
**HHUS** handheld ultrasound
**DM** digital mammography
**ABUS** automated breast ultrasonography
**CAD** computer-aided detection
**MRI** magnetic resonance imaging
**3D** three-dimensional

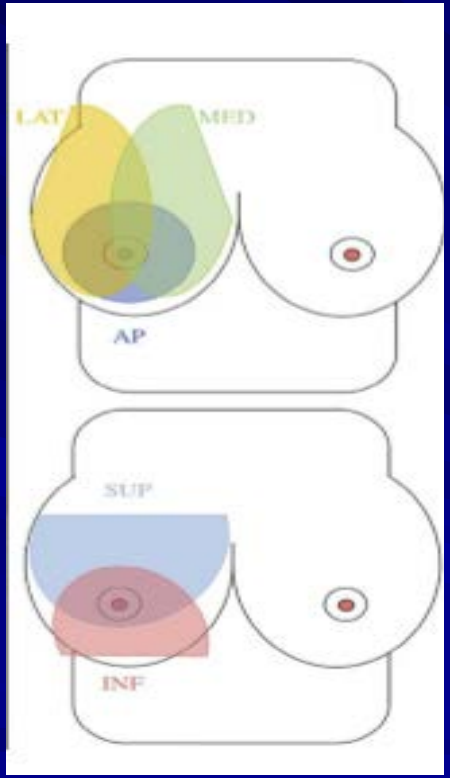
Automated breast ultrasonography (ABUS) is a new imaging technology for automatic breast scanning through ultrasound. It was first developed to overcome the limitation of operator dependency and lack of standardization and reproducibility of handheld ultrasound. ABUS provides a three-dimensional representation of breast tissue and allows images reformatting in three planes, and the generated coronal plane has been suggested to improve diagnostic accuracy.

This technique has been first used in the screening setting to improve breast cancer detection, especially in mammographically dense breasts. In recent years, numerous studies also evaluated its use in the diagnostic setting: they showed its suitability for breast cancer staging, evaluation of tumor response to neoadjuvant chemotherapy, and second-look ultrasound after magnetic resonance imaging.

The purpose of this article is to provide a comprehensive review of the current body of literature about the clinical performance of ABUS, summarize available evidence, and identify gaps in knowledge for future research.

**Key Words:** Automated breast ultrasound; breast cancer; ultrasonography; coronal view; 3D scanning.




LAT
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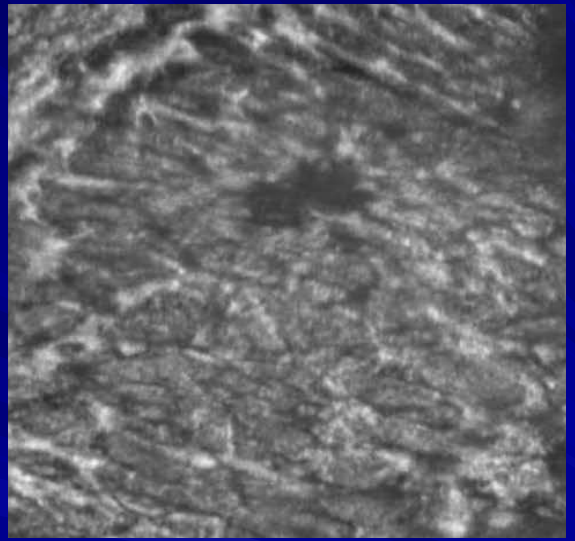


**TABLE 1. Diagnostic Performance of ABUS**

| Study author | Patients (Lesions, BC) | Mean age y (range) | SE (%) | SP (%) | FPR (%) | FNR (%) | PPV | NPV | Reference standard | Comparative accuracy to HHUS | Additional relevant findings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chang** (24) | N.R. (105, 24) | 47±14 (20–79) | 92.5 | 63 | 37.0 | 7.5 | 56.41 | 93.55 | Histology or imaging FUP (mean 11.1±10.4 months, range 0–31 months) | N.R. | Mean diameter of the lesion, surrounding tissue changes and shape of the mass were the final most important factors associated with lesion detectability. |
| **Chang** (25) | 61 (62, 14) | 45 (32-62) | 71.4* | 86.1* | 14.6 | 28.6 | 58.8 | 91.1 | Histology or imaging FUP (mean 15 months, range 15–26 months) | N. R. | The mean time to interpret the 3D ABUS data per breast was 4.5 minutes (range 3.5–7.5 minutes) for reader 1, 4.0 minutes (range 3.0–7.0 minutes) for reader 2, and 5.5 minutes (range 3.5–9.5 minutes) for reader 3. |
| **Chen** (14) | 175 (219, 67) | 41.7 (16-71) | 92.5 | 86.2 | 13.8 | 7.5 | 74.7 | 96.3 | Histology or FUP (not specified) | N.S. HHUS: SE 88.1%, SP 87.5%, FPR 12.5%, FNR 11.8%, PPV 75.6%, NPV 94.3% | There were significant differences between malignant and benign masses with respect to the retraction phenomenon and hyperechoic rim. |
| **Cho** (26) | 141 (150, 60) | 46 (25–71) | 98.3† | 70.0† | 30.0 | 1.7 | 68.6 | 98.4 | Histology or imaging FUP (mean 20 months, range 12–26 months) | N.S. HHUS: SE 96.7%, SP 64.4% | Interobserver agreements between the four radiologists for final assessment of solid breast masses were similar for 2D and 3D US images ($P > .05$). |
| **Golatta** (27) | 42 (N.R., 20) | 51 (33-83) | 82.0 | 68.0 | 12 | 12 | 81.31 | 69 | Histology | N. R. | |
| **Golatta** (28) | 983 (N.R., 119) | 55.7 (19–92) | 84.0 | 85.0 | 15.0 | 16.0 | 27.0 | 99.0 | Combination of HHUS, mammography and histology | N.R. | Fair agreement (k = 0.25–0.31) of ABUS with HHUS and mammography but total agreement rates for dichotomized (benign versus malignant) lesions |
| **Jeh** (29) | 173 (206, 46) | 48 (20-80) | 88.05†* | 76.25†* | 23.75‡ | 11.95‡ | 52.25‡ | 95.95‡ | Histology | HHUS: SE 95.7% ($P > .05$), SP 49.4 ($P < .0001$) | Smaller lesions and lesions with lower final-assessment category were less frequently detected on ABUS ($P < .011$ and $P < .0001$, respectively). |
| **Kim** (30) | 87 (106, 52) | N.R. | 89.2 | 79.0 | 21.0 | 10.8 | 81.31 | 94.1 | Histology or imaging FUP (mean 49 months, range 24–126) | N.S. HHUS: SE 98.7%, SP 80.1% | Final assessment of solid breast masses showed substantial to almost perfect agreement between HHUS and ABUS (k= 0.773±0.104) |
| **Kim** (31) | 38 (66, 50) | N.R. | 92.0 | 87.5 | 12.5 | 8.0 | 95.8 | 77.8 | Histology | N.S.HHUS: SE 98.0%, SP 62.5% | Overall agreement for mass size, shape, posterior features, orientation and BI-RADS category was moderate while the overall agreement for margins was fair (κ = 0.25) |
| **Lin** (32) | N.R. (35, 15) | 40.7 (16–78) | 100.0 | 95.0 | 5.0 | 0.0 | 93.7 | 100.0 | Histology | N.S. HHUS: SE 100.0%, SP 85.0% | Perfect agreement between ABUS and pathological diagnosis (k=0.942) |
| **Kotsianos-Hermle** (33) | 97 (107, 39) | 52.4 (21-78) | 96.5 | 92.3 | 7.7 | 3.5 | N.R. | N.R. | Histology | N.S.HHUS: SE 97.5%, SP 88.5% | Correlation was good between ABUS and HHUS for the BIRADS criterion "margins" (k=0.88) |
| **Shin** (34) | 55 (145, 28) | 48 (29–69) | 96.0§ | 91.8§ | 8.2 | 4.0 | N.R. | N.R. | Combination of HHUS, mammography and histology | N.S.HHUS: SE 100.0%, SP 93.0% | Lesion detection was reliable (92%) only when mean lesion diameter was>1.2 cm |
| **Wang** (35) | 213 (239, 85) | 43.0±12.5 (11-81) | 95.3 | 80.5 | 19.5 | 4.7 | 73.0 | 93.3 | Histology | N.S.HHUS: SE 90.6%, SP 82.5% | |
| **Wang** (36) | 155 (165, 103) | 43.1±21.2 (23-65) | 96.1 | 91.9 | 8.1 | 3.9 | 95.2 | 93.4 | Histology | N.S.HHUS: SE 93.2%, SP 88.7% | The stellate margin had a high specificity (98.4%) but a low sensitivity (57.5%), with an accuracy to determine malignant and benign lesions of 73.9% |
| **Wojcinski** (37) | 50 (50, 14) | 52 (32-72) | 100 | 52.8 | 47.2 | 0.0 | 45.2 | 100.0 | HHUS | | |
| **Wojcinski** (38) | 100 (100, 18) | 52 (19-86) | 83.3 | 78.1 | 21.9 | 16.7 | N.R. | N.R. | HHUS | | |
| **Schmachtenberg** (39) | 28 (39, 15) | 44.6 (26-76) | 93.3 | 83.3 | 16.7 | 6.7 | 77.8 | 95.2 | HHUS, MRI and histology (if available) | N.S.HHUS: SE 100.0%, SP 83.3% | |

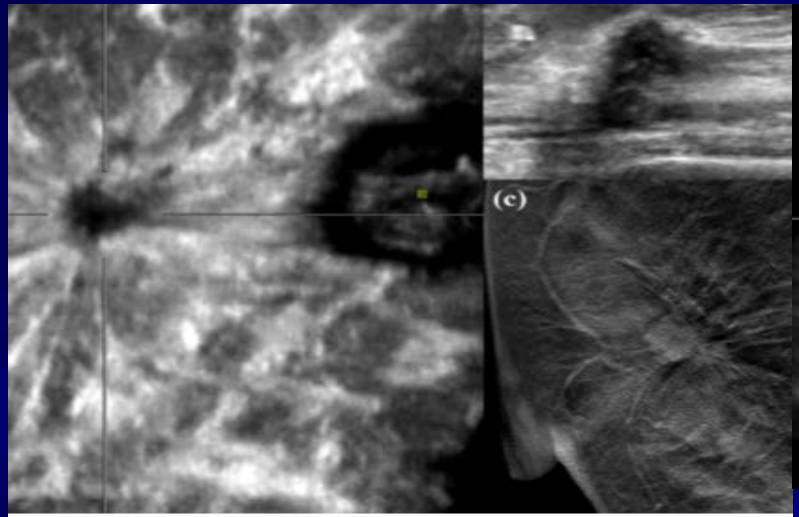
BC, Breast cancer; FNR, false negative rate; FPR, false positive rate; FUP, follow-up; HHUS, hand-held ultrasound; N.R., not reported; N.S., not significant ($P > .05$); NPV, negative predictive value; PPV, positive predictive value; SE, sensitivity; SP, specificity.

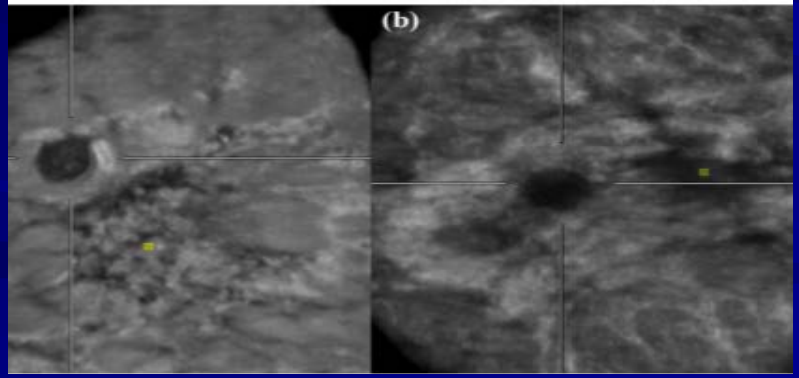
* Combined evaluations of three readers (data for readers are, respectively, Sensitivity 78.6, 78.6 and 57.1%; Specificity 79.2, 87.5 and 91.7%).

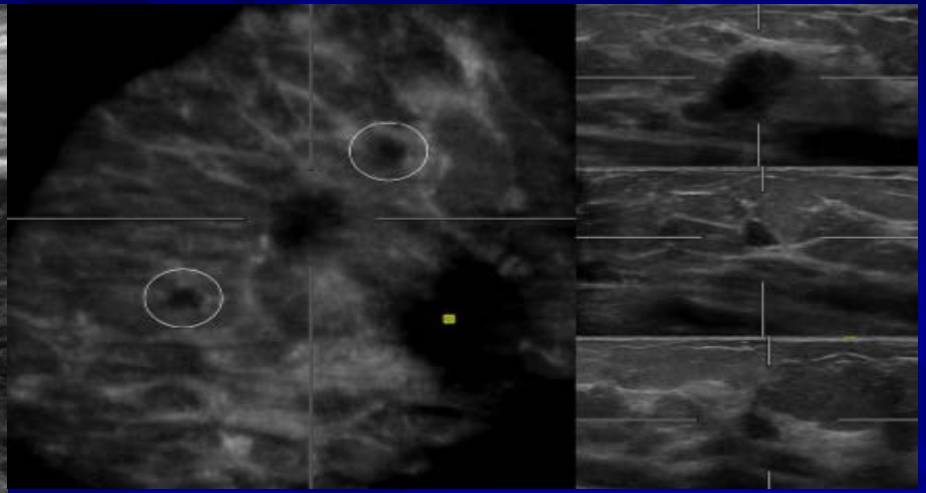
† Combined evaluations of four readers (data for readers are, respectively, Sensitivity 100, 100, 98 and 93%; Specificity 58, 51, 83 and 86%).

‡ Mean value of two readers (data for readers are, respectively, Sensitivity 95.7 and 80.4%; Specificity 70.6 and 81.9%).

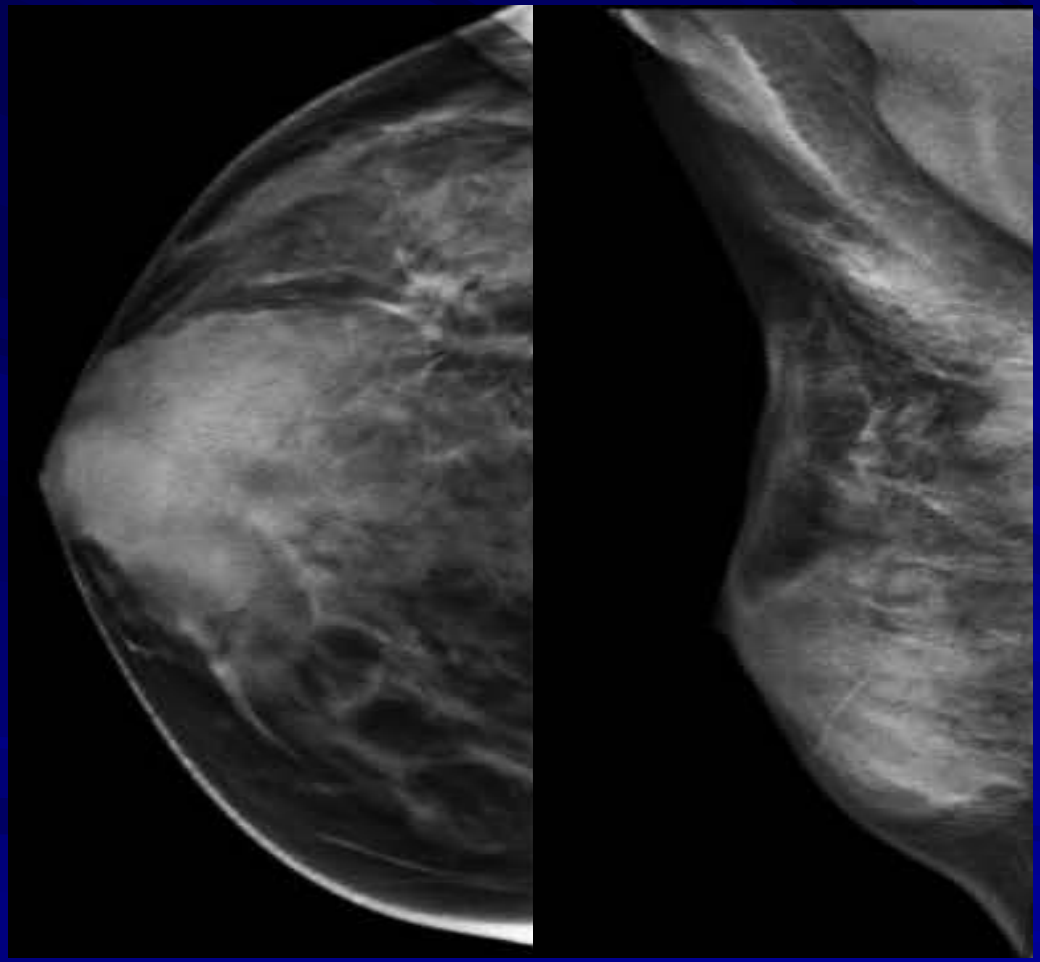
§ Mean value of five readers (data for readers are, respectively, Sensitivity 100, 90, 100, 93 and 97%; Specificity 92, 91, 86, 96 and 94%).

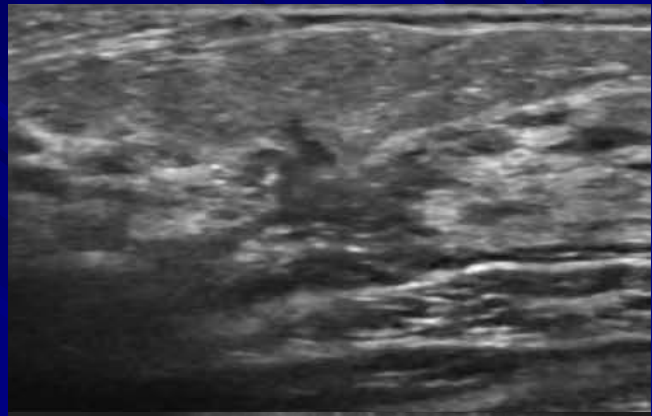


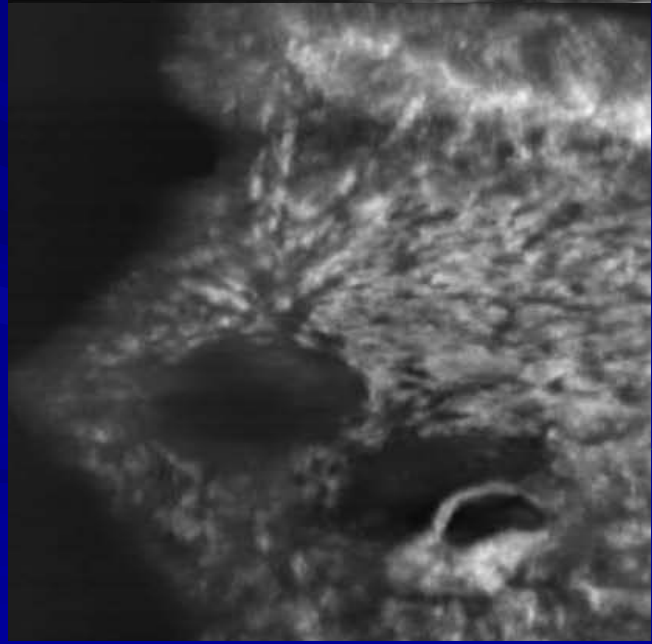



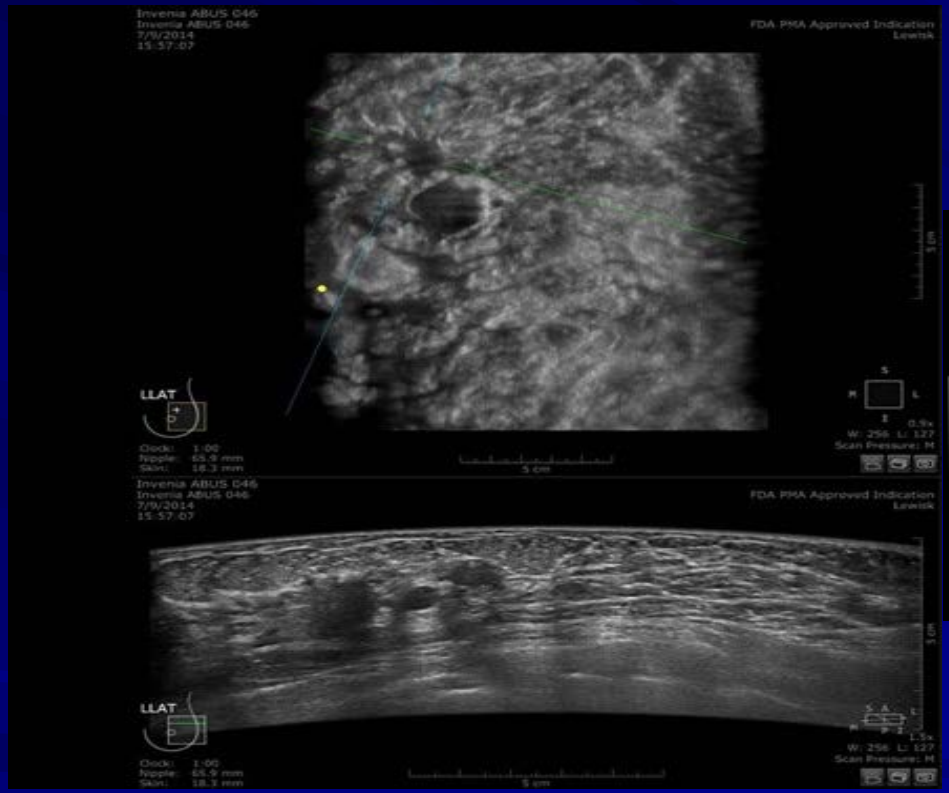



Staging is mandatory in the planning of breast conserving surgery. Magnetic resonance imaging (MRI) is the most used modality for this purpose, but ABUS can be proposed as a valuable tool for operative planning, since it constitutes a global visualization of the lesion and its surroundings, especially in the coronal plane (“surgical view”).





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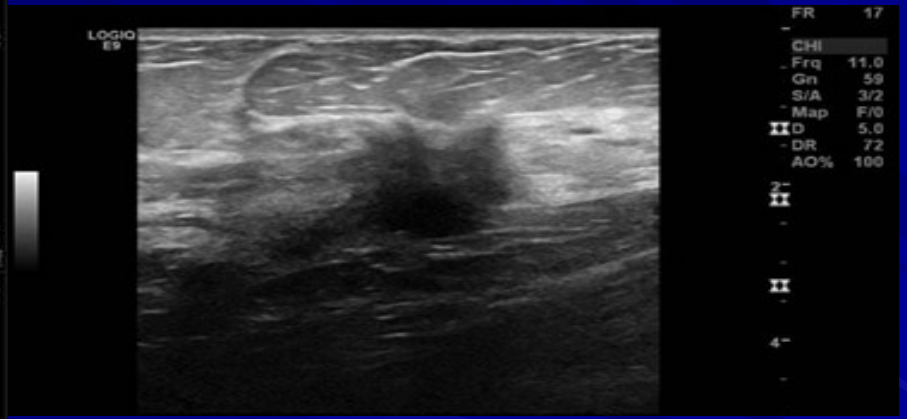
Scan Pressure: M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E9
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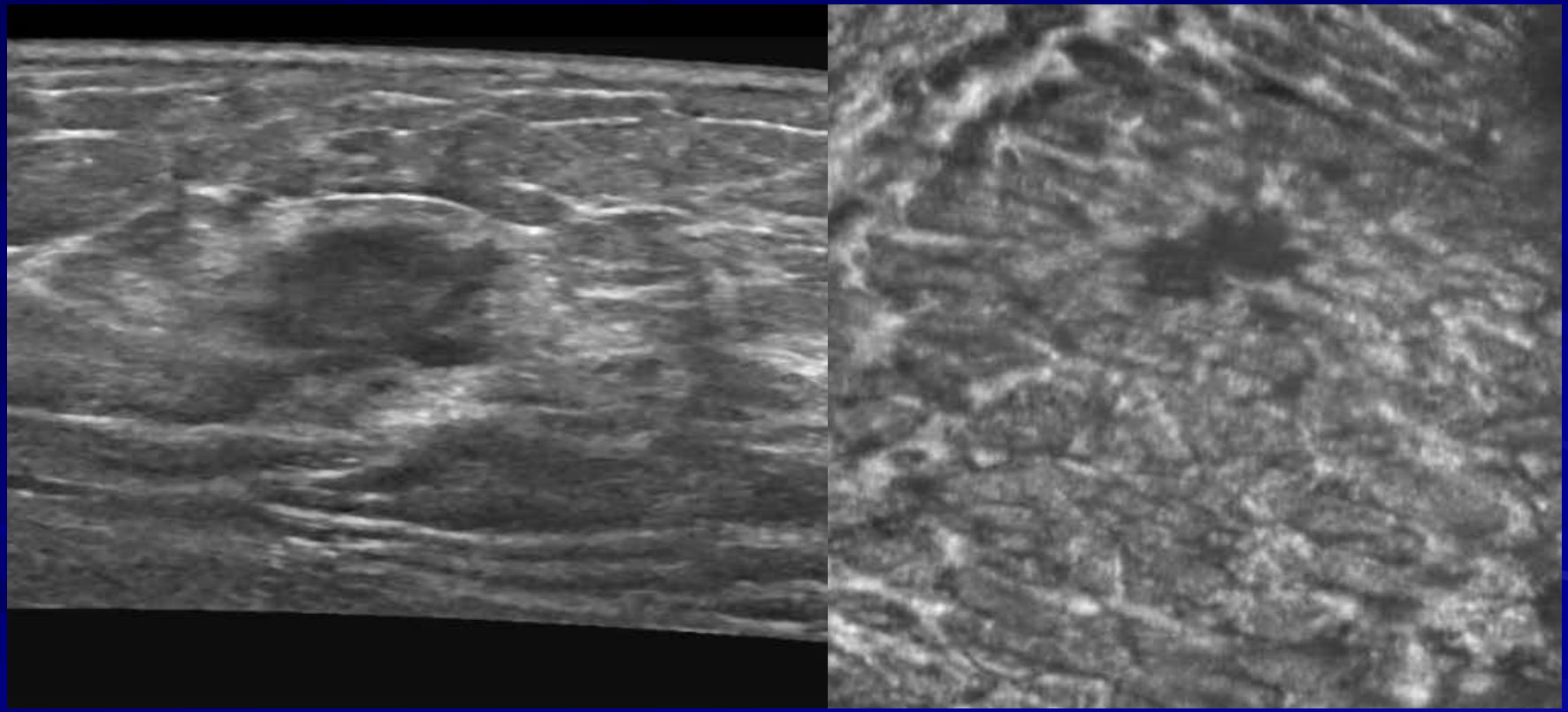
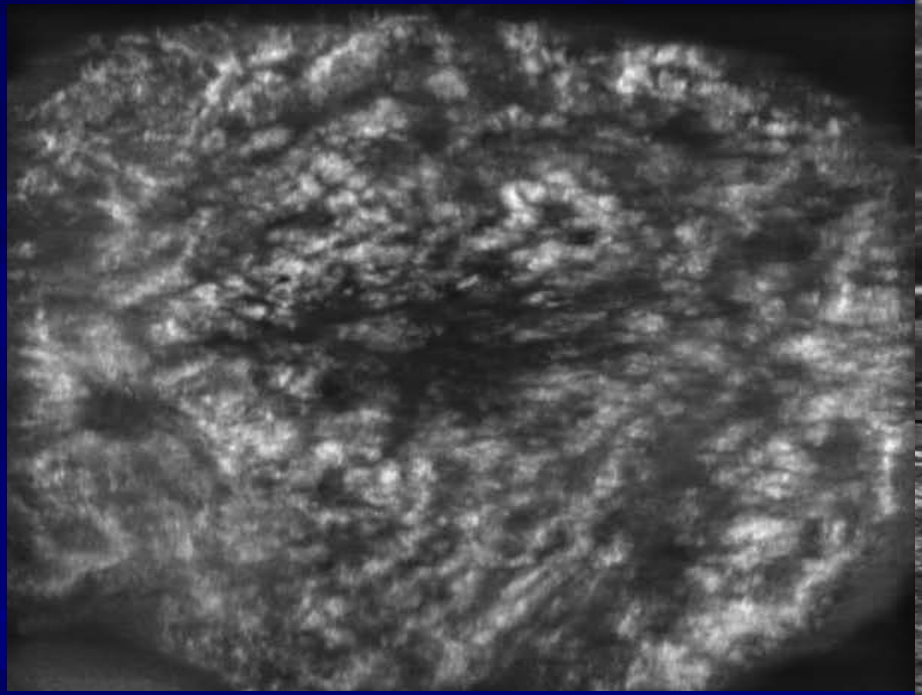
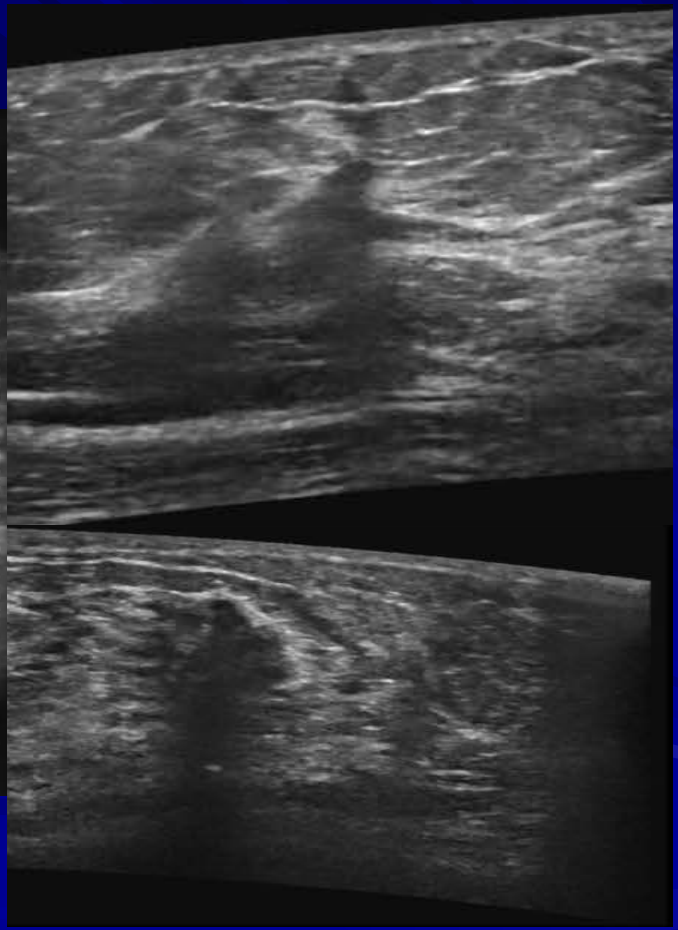
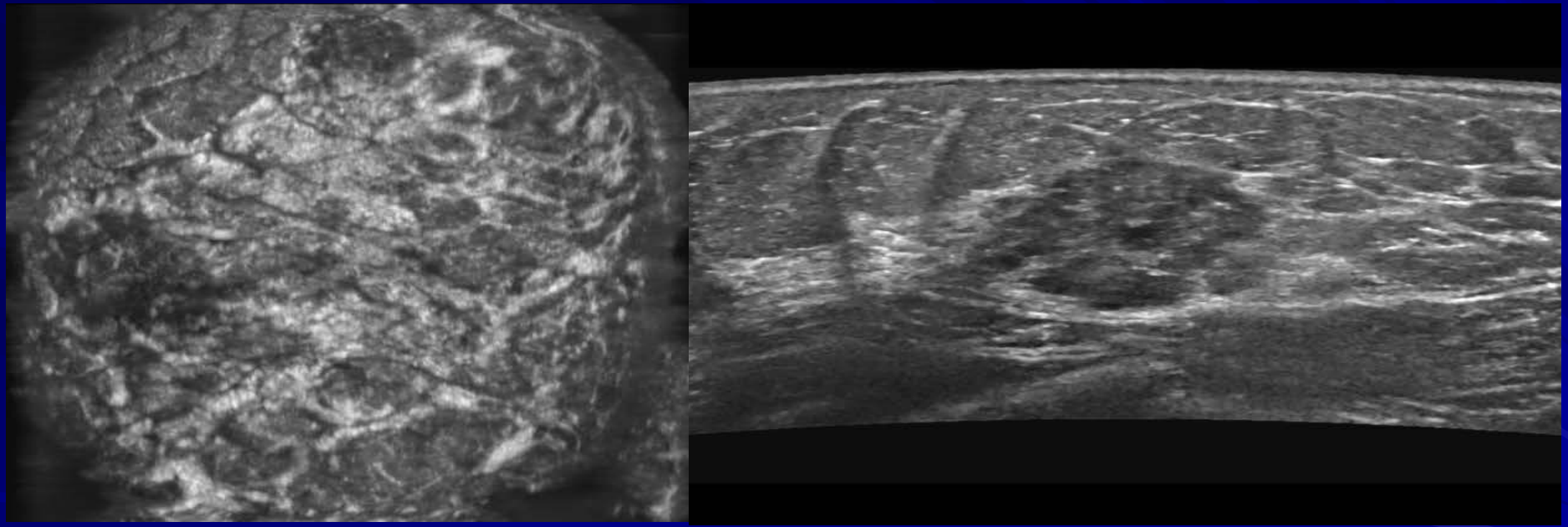
CHI
Frq 11.0
Gn 59
S/A 3/2
Map F/0
D 5.0
DR 72
AO% 100









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journal homepage: www.elsevier.com/locate/ejrad

Research article

# Breast cancer staging: Combined digital breast tomosynthesis and automated breast ultrasound versus magnetic resonance imaging

Rossano Girometti, Ludmila Tomkova*, Lorenzo Cereser, Chiara Zuiani

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ARTICLE INFO

*Keywords:*
Breast cancer
Digital breast
Tomosynthesis
Automated breast volume scanner
Magnetic resonance imaging

ABSTRACT

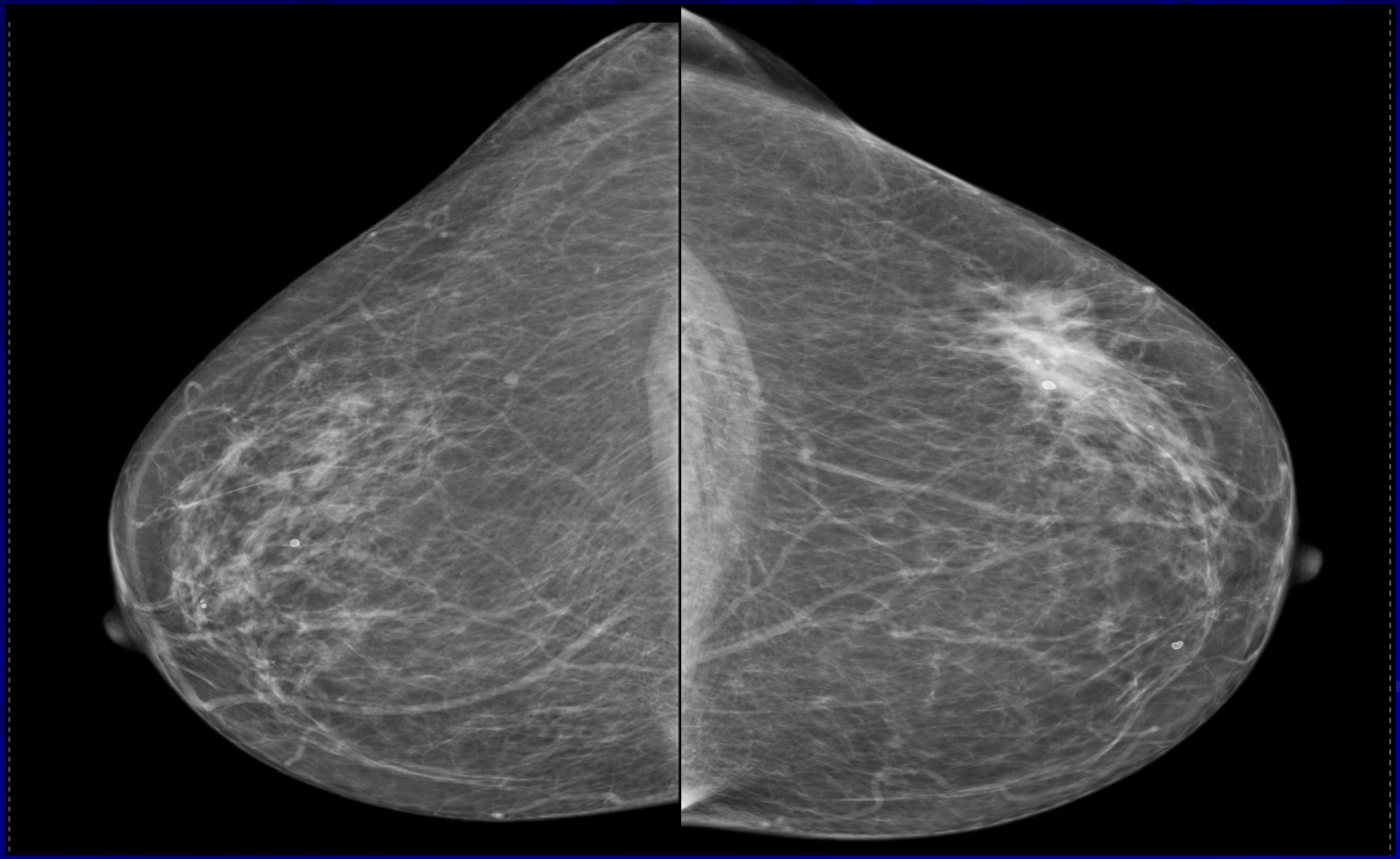
*Purpose:* To investigate whether combined Digital breast tomosynthesis and Automated breast volume scanner (DBT-ABVS) are comparable to Magnetic resonance imaging (MRI) in staging breast cancer.

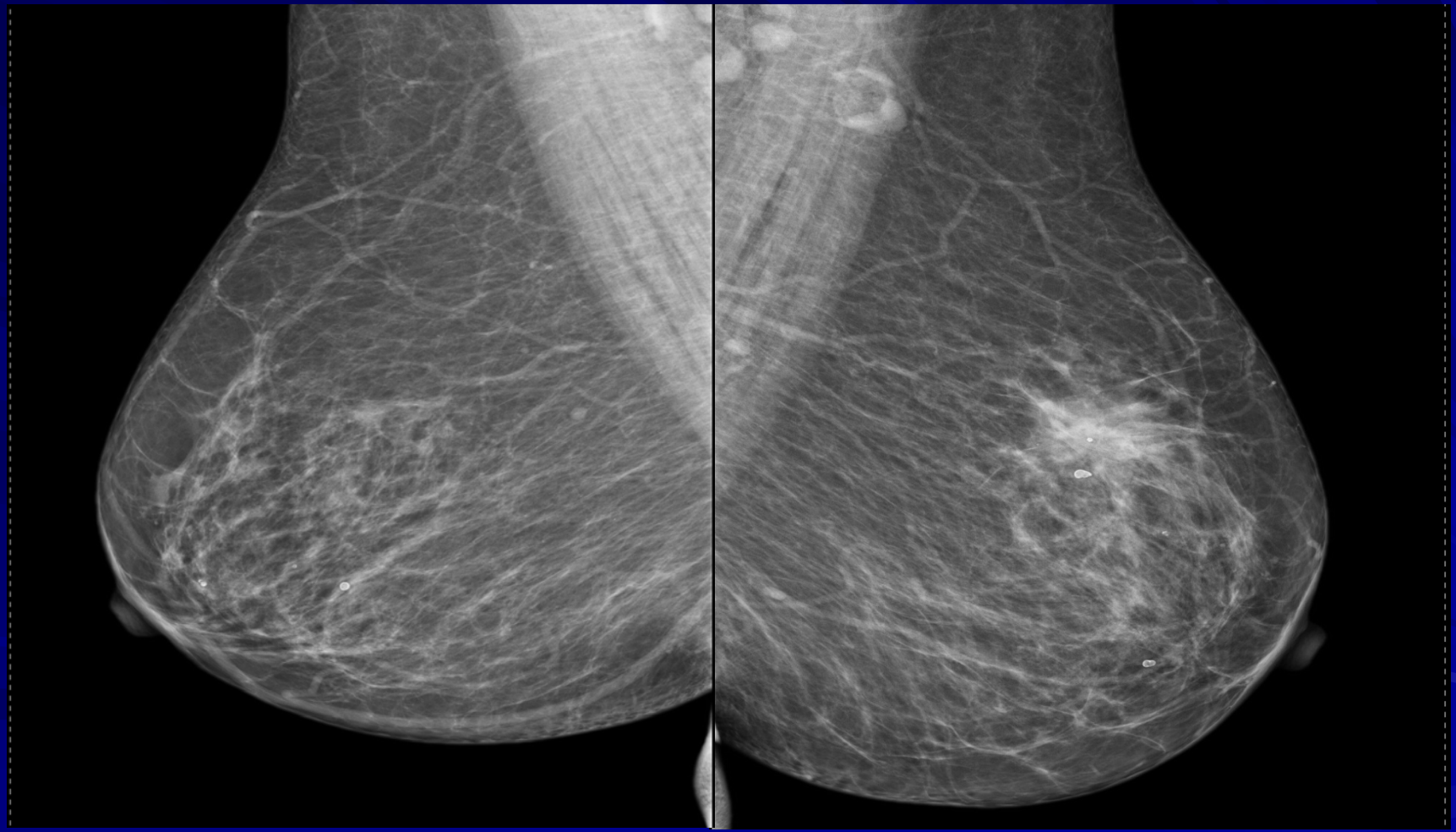
*Methods:* We retrospectively included seventy-three patients with histologically proven breast cancer who underwent preoperative DBT, ABVS and 1.5 T MRI in the period July 2015–July 2016. Two radiologists in consensus recorded the number, site and Breast imaging-reporting and data system (BI-RADS) category of breast findings during two independent reading strategies, i.e. DBT-ABVS vs. MRI. Using histology or 1-year follow up as the standard of reference, we calculated the accuracy for cancer of both imaging strategies. Bland-Altman analysis was used to evaluate the agreement between MRI vs. DBT or ABVS in cancer size assessment.

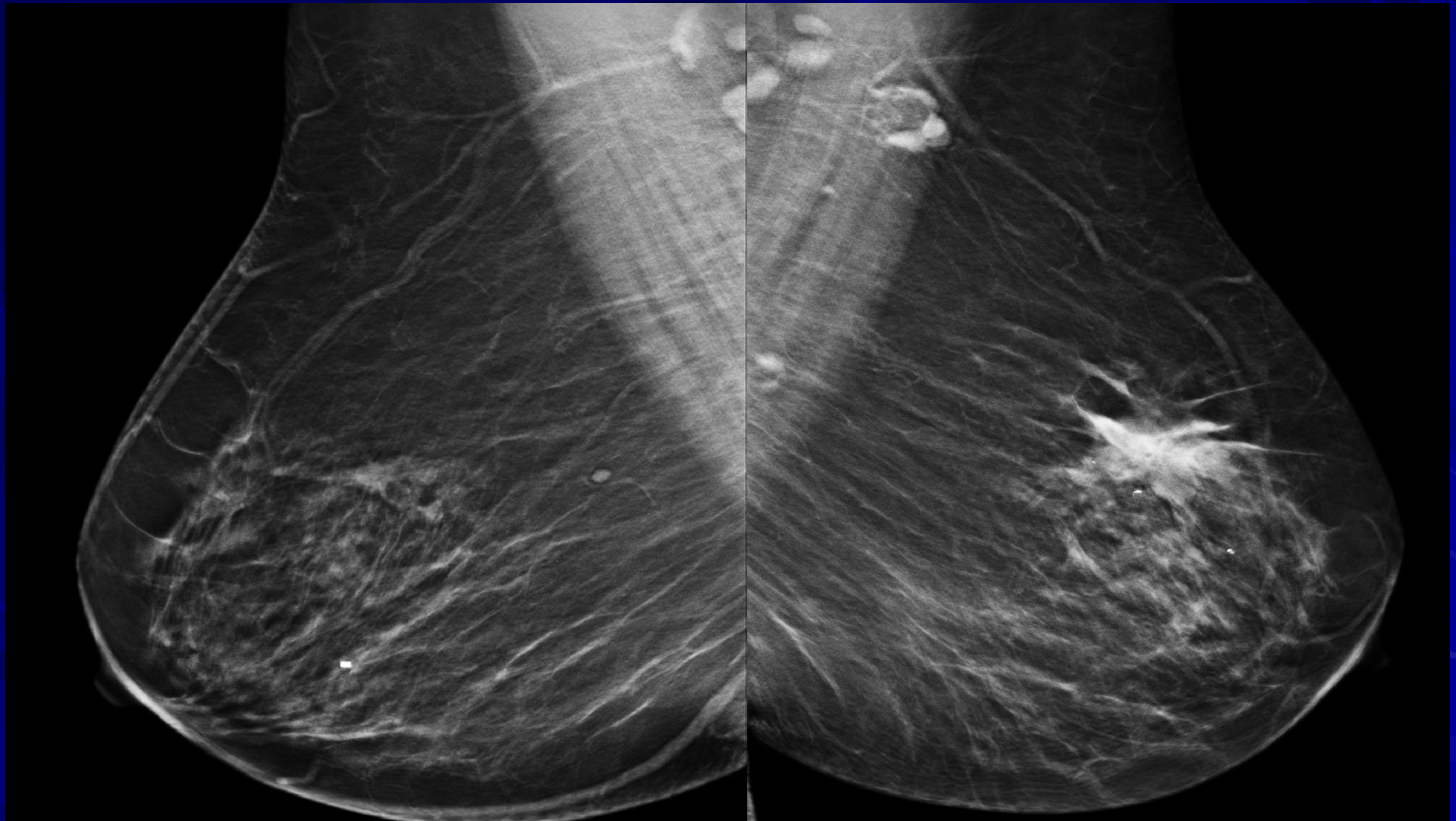
*Results:* Patients showed a total of 160 lesions (108 malignant and 52 benign). Malignant lesions were unifocal, multifocal, multicentric and biltateral in 53, 15, 4 and 1 cases, respectively. Diagnostic accuracy of DBT-ABVS vs. MRI was comparable for all cancers (90.0% [95%C.I. 84.3–94.2] vs. 93.8% [95%C.I. 88.8–97.0], respectively). DBT-ABVS showed lower sensitivity and positive predictive values for additional disease (76.5% [95%C.I. 58.8–89.3] vs. 91.7% [95%C.I. 84.6–96.1], and 78.8% [95%C.I. 61.0–91.0] vs 93.4% [95%C.I. 86.9–97.3], respectively). Compared to MRI, ABVS + DBT missed 6 lesions, including two invasive cancers and one extensive intravascular invasion associated to ductal carcinoma in situ. Bland-Altman analysis showed ABVS to agree with MRI at a higher extent than DBT in assessing cancer size.

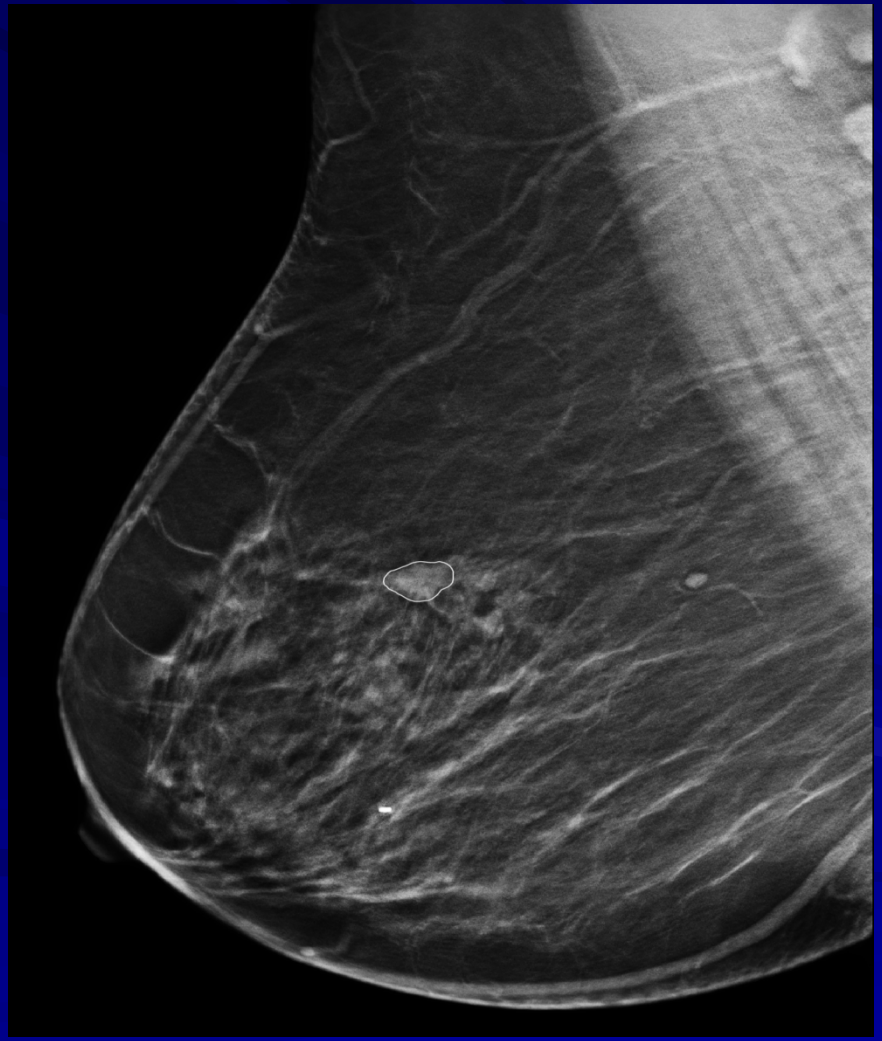
*Conclusions:* Though less performing than MRI, DBT-ABVS showed acceptable diagnostic accuracy in staging breast cancer. This strategy might be used if MRI is unavailable or unfeasible.

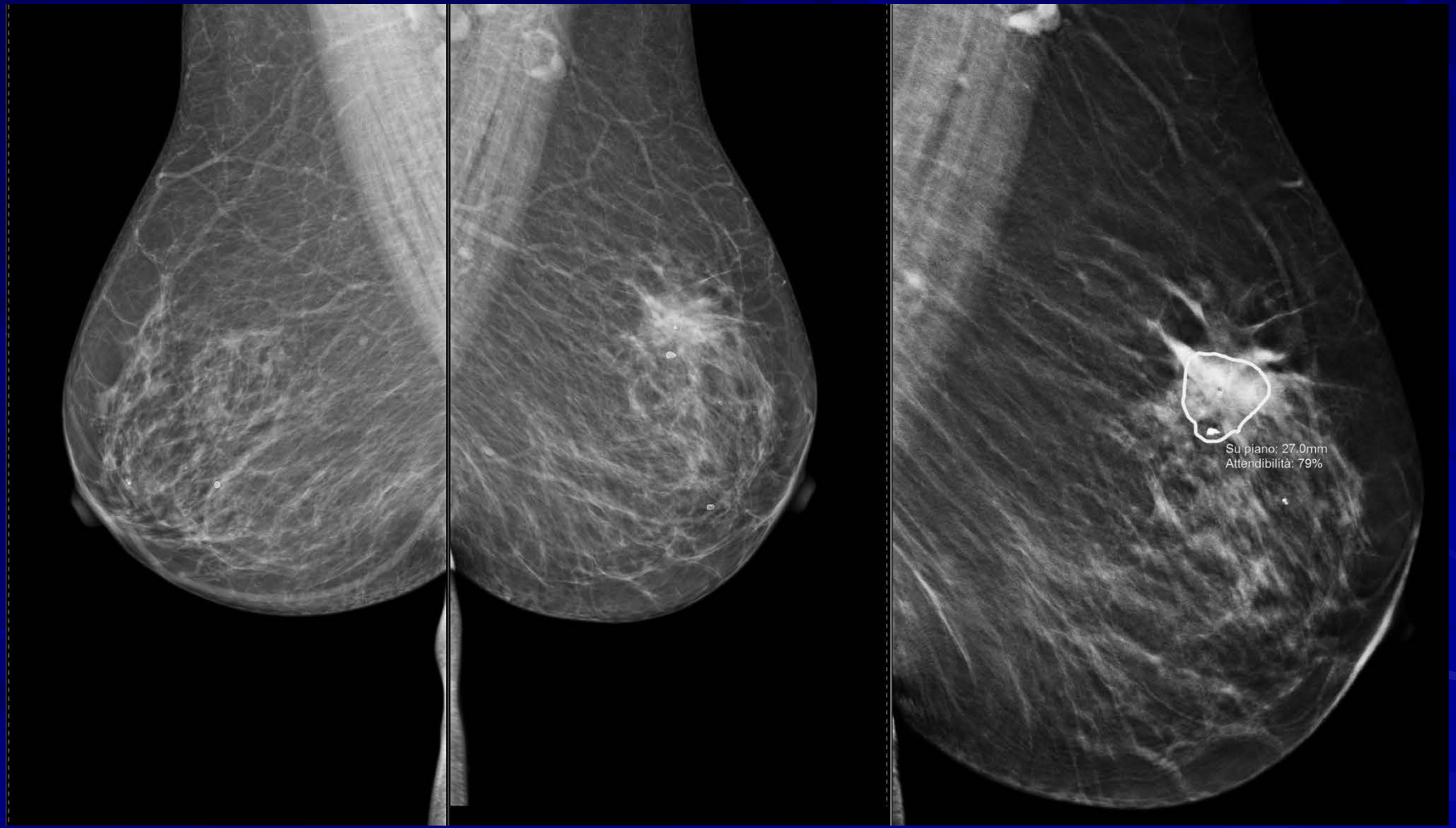
| | TP (n) | FN (n) | FP (n) | TN (n) | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Accuracy (%) |
|---|---|---|---|---|---|---|---|---|---|
| **All lesions** | | | | | | | | | |
| DBT-ABVS | 99 | 9 | 7 | 45 | 91.7 (84.6 – 96.1) | 86.5 (74.2 – 94.4) | 93.4 (86.9 – 97.3) | 83.3 (70.8 – 92.1) | 90.0 (84.3 – 94.2) |
| MRI | 104 | 4 | 6 | 46 | 96.3 (90.8 – 99.0) | 88.5 (76.6 – 95.6) | 94.5 (89.1 – 97.4) | 92.0 (81.4 – 96.8) | 93.8 (88.8 – 97.0) |
| **Non index lesions** | | | | | | | | | |
| DBT-ABVS | 26 | 8 | 7 | 45 | 76.5 (58.8 – 89.3) | 86.5 (74.2 – 94.4) | 78.8 (61.0 – 91.0) | 84.9 (72.4 – 93.3) | 82.6 (72.9 – 89.9) |
| MRI | 31 | 3 | 6 | 46 | 91.2 (76.3 – 98.1) | 88.5 (76.6 – 95.6) | 83.8 (68.0 – 93.8) | 93.9 (83.2 – 98.7) | 89.5 (81.1 – 95.1) |

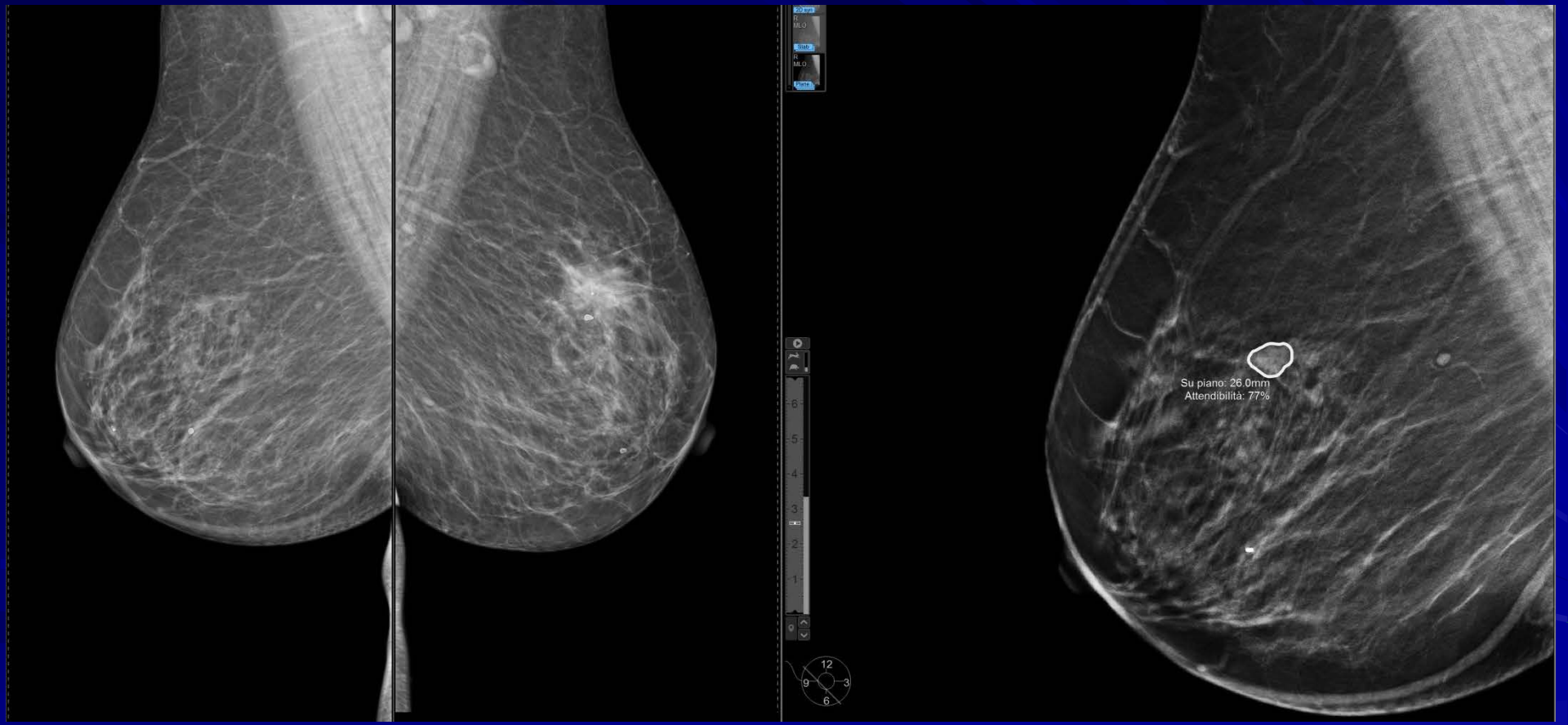


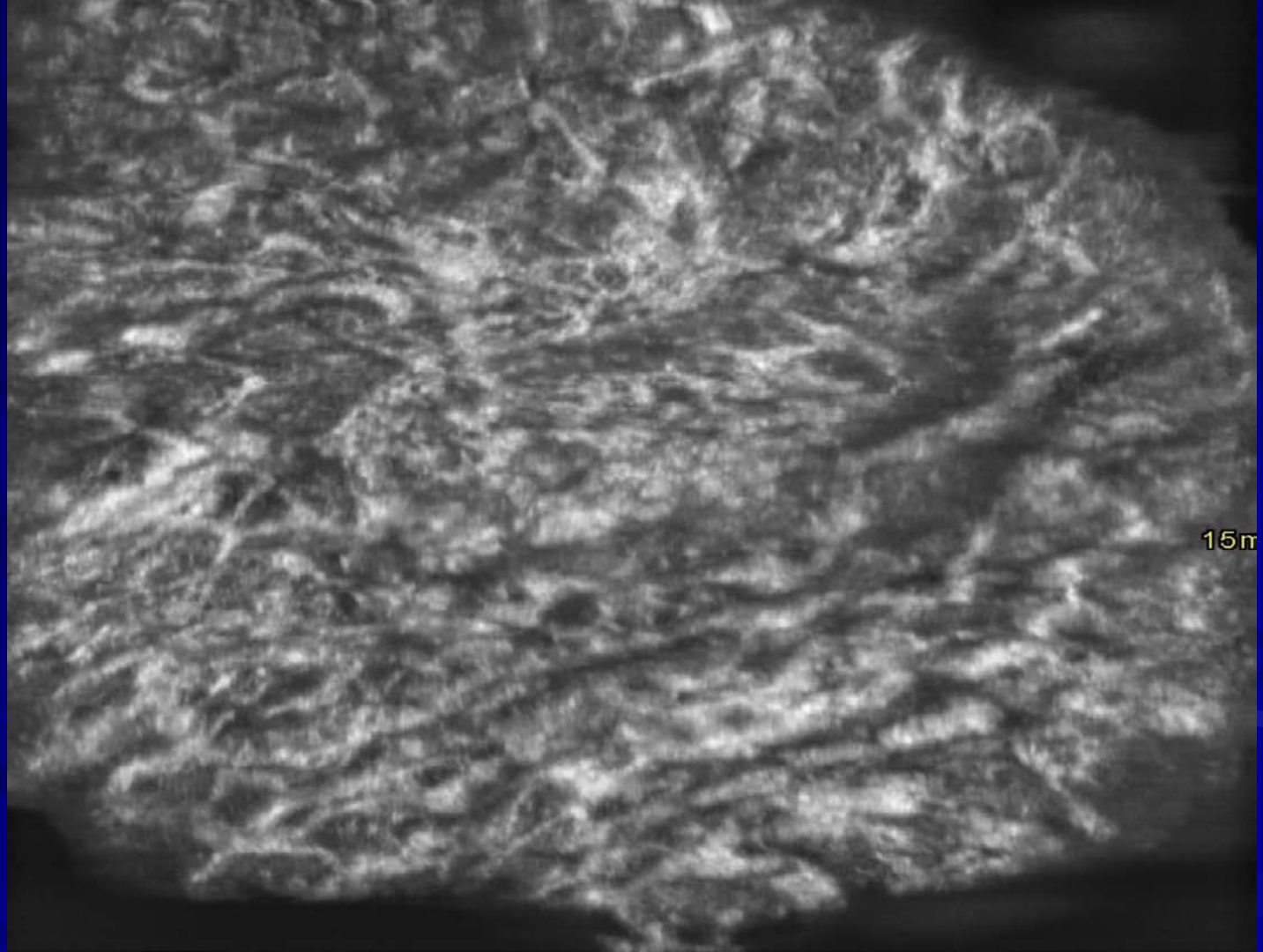


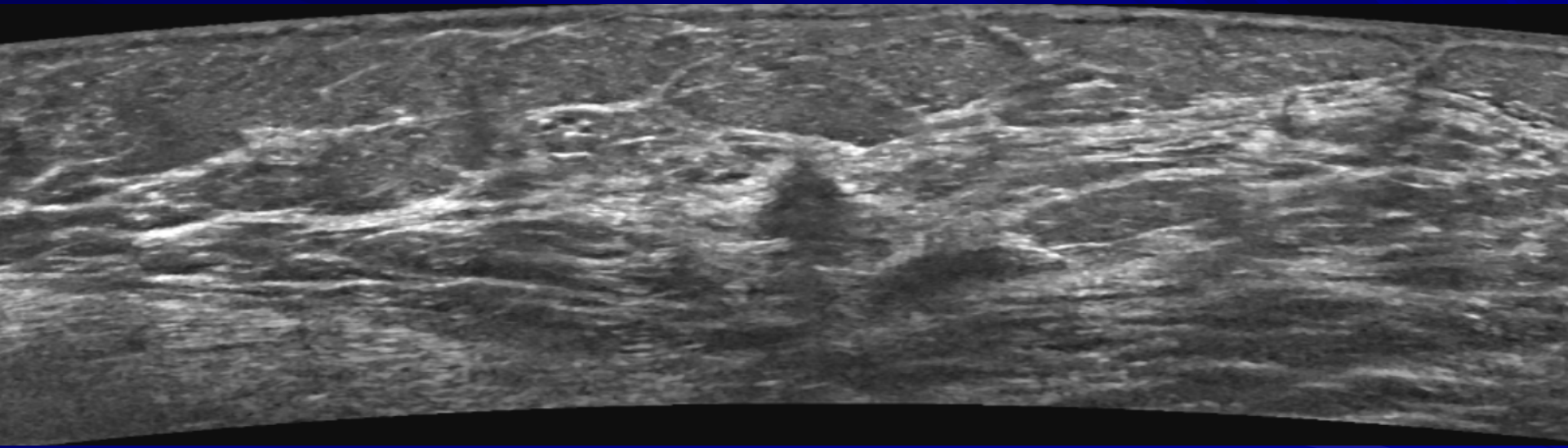


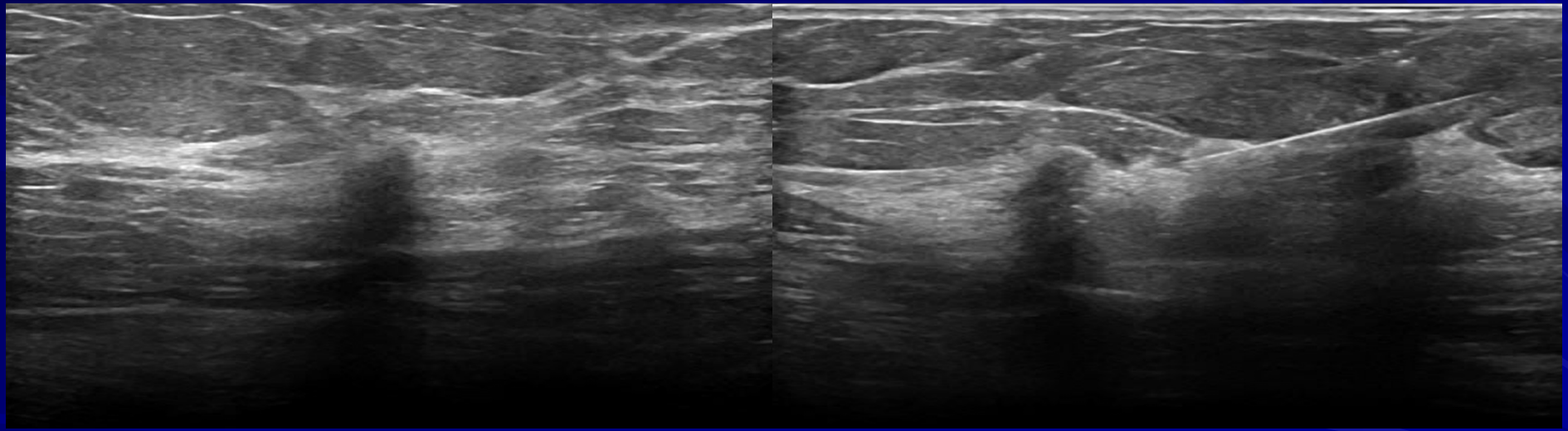



Su piano: 27.0mm
Attendibilità: 79%


Su piano: 26.0mm
Attendibilità: 77%


15m





# IMAGING CON MDC

- RM
- CEM

# Protocollo di studio RM per la mammella

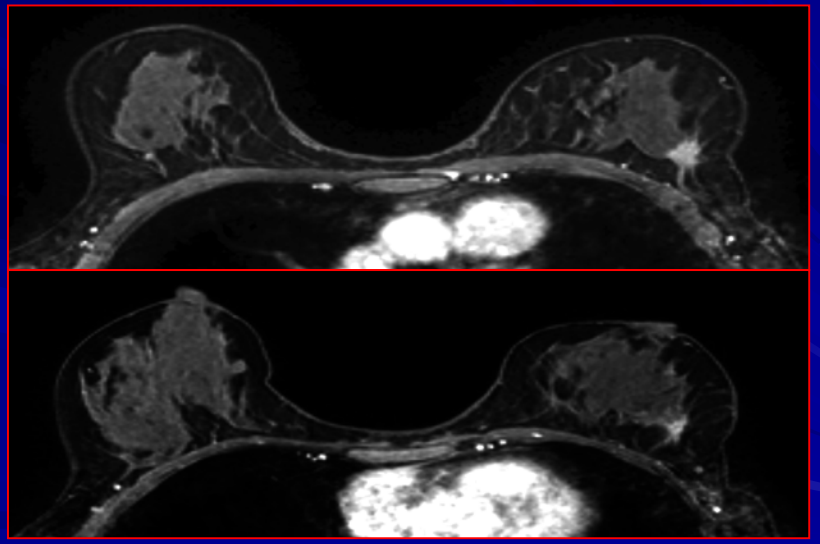
- Survey: immagine guida con sequenze di localizzazione T1 pesata
- Sequenza assiale **STIR** (Short TI Inversion Recovery Turbo Spin Echo) con soppressione del segnale del grasso
  - TR/TE/TI = 3,800/60/165 ms,
  - FOV = 250x 450 mm (AP X RL),
  - matrice di acquisizione 168 x 300,
  - 50 acquisizioni con spessore di strato 3 mm,
  - fattore turbo 23
- Sequenza assiale **T2 pesata TSE**
  - TR/TE=6300/130ms,
  - FOV=250x450mm (APXRL),
  - matrice di acquisizione 336x600
  - 50 acquisizioni con spessore di strato 3 mm senza intervallo,
  - fattore turbo 59

- **Indagine dinamica: sequenza T1 pesata gradient-echo volumetrica THRIVE**
  - **TR/TE=4.4/2.0 ms,**
  - **FOV=250x450x150 mm (APxRLxFH),**
  - **matrice di acquisizione 168x300,**
  - **100 acquisizioni con spessore di strato 1,5 mm,**
  - **fattore turbo 50**

**Acquisizione basale seguita da cinque acquisizioni dinamiche della durata ciascuna di 1.30 minuti per una durata complessiva di 7 minuti circa previa somministrazione endovenosa di gadolinio**

# Caratterizzione RM dinamica

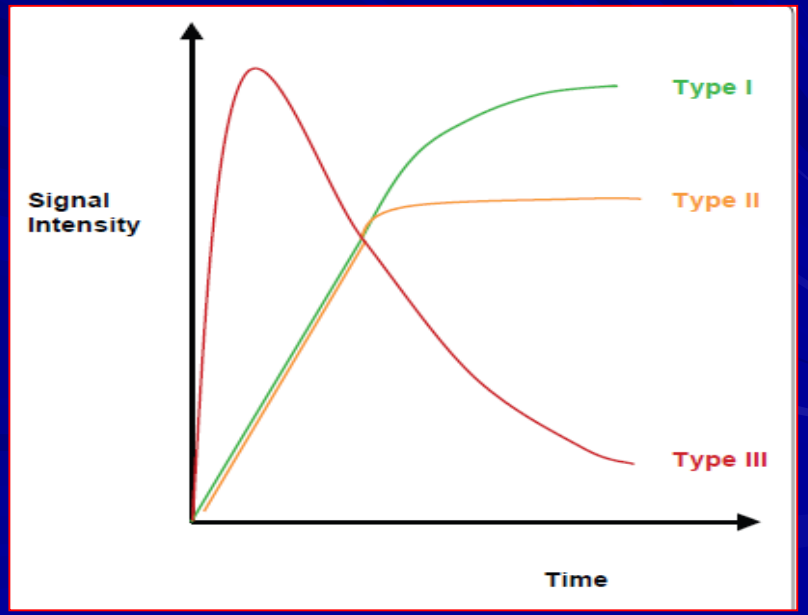
- **ENHANCEMENT**
  - Focale (diametro inferiore a 5 mm)
    - NATURA ORMONALE
    - DCIS
  - mass-like
  - non mass like



- **MORFOLOGIA**
- **MARGINI**
- **CINETICA INTRA-LESIONALE DEL MDC MEDIANTE CURVE IS/T**

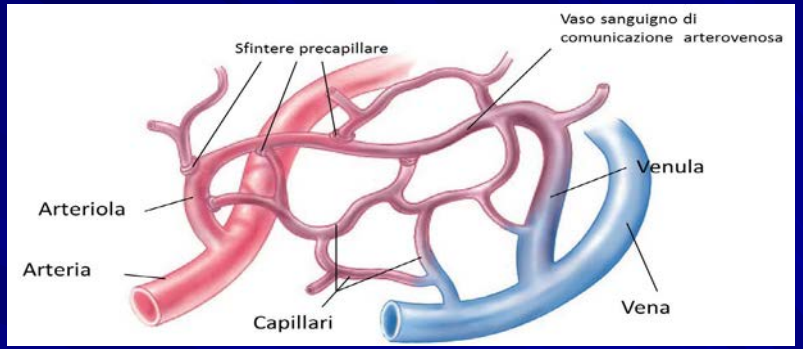
# Post - processing delle immagini

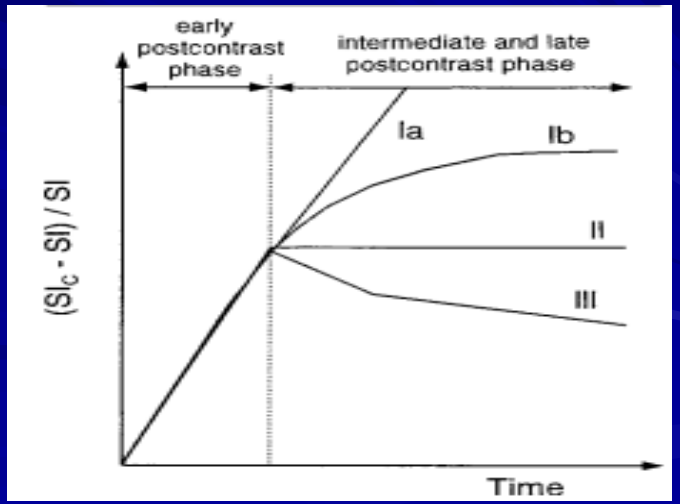
- Sottrazione dell’immagine
- MIP
- MPR
- Curve di enhancement Is/t



# TIC ANALYSIS CE IMAGES

- The shape of **TICs** depends on **contrast material wash-in** and **wash-out** of breast lesions;
- **Contrast material wash-in** had a **low value of specificity** justified by many benign lesions showing enhancement rates similar to those of malignant ones;
- **Contrast material wash-out** represents a **very specific but a not very sensitive** sign of malignancy. In fact, wash-out phenomenon is found only in 57% of breast cancers.



Original Study

# Abbreviated Combined MR Protocol: A New Faster Strategy for Characterizing Breast Lesions

Marco Moschetta, Michele Telegrafo, Leonarda Rella, Amato Antonio Stabile Ianora, Giuseppe Angelelli

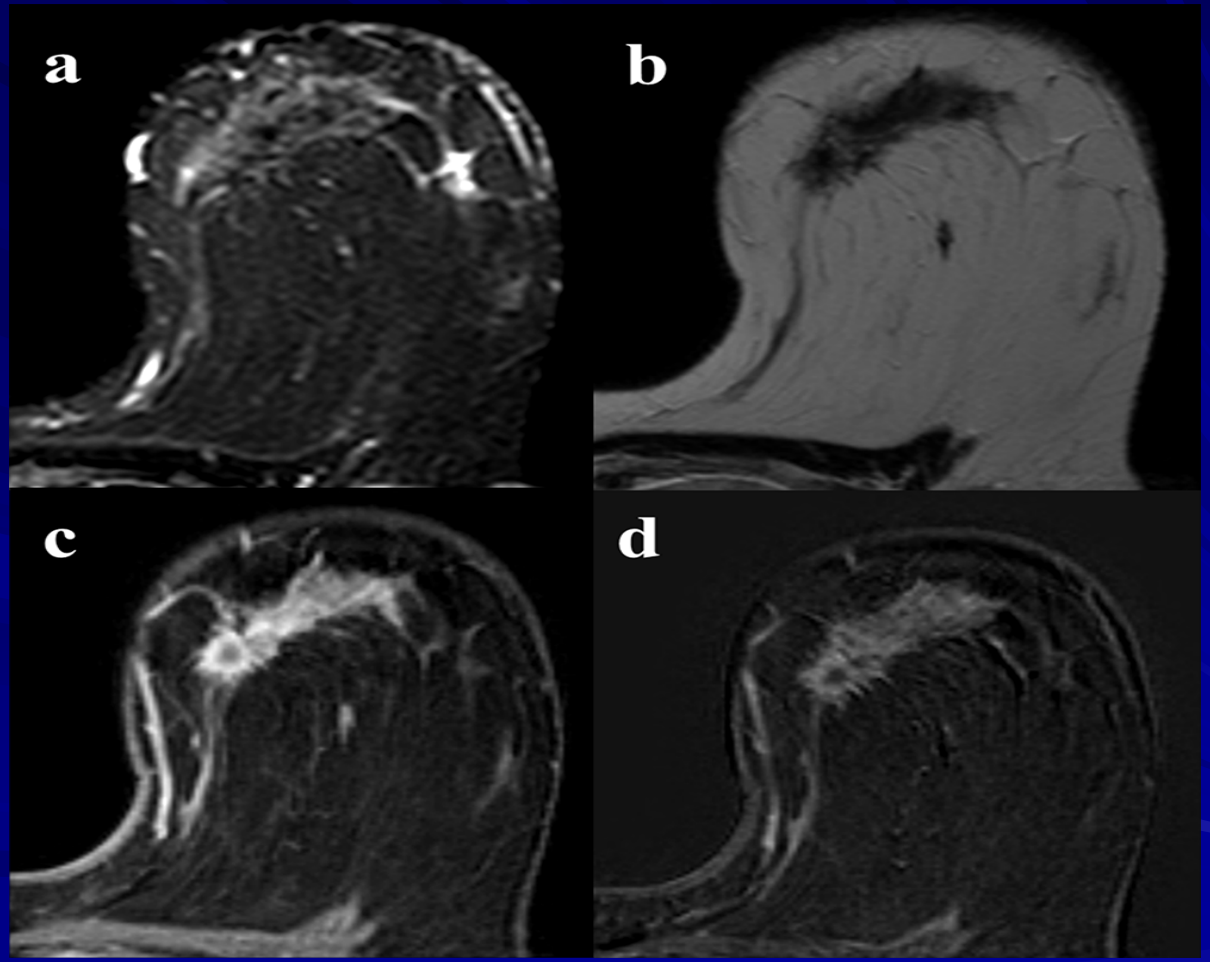
## Abstract

**The use of an abbreviated magnetic resonance protocol consisting of 1 pre- and post-contrast T1 weighted sequence has been proposed in order to screen for breast cancer. We propose an abbreviated magnetic resonance protocol combining short TI inversion recovery, turbo spin echo-T2 sequences, a pre-contrast fat saturation T1 weighted, and a single intermediate post-contrast fat saturation T1 weighted sequence with the corresponding subtracted series. It represents a time-saving tool with the same diagnostic potential as the standard protocol for characterizing breast lesions.**

**Background:** The use of an abbreviated magnetic resonance (MR) protocol has been recently proposed for cancer screening. The aim of our study is to evaluate the diagnostic accuracy of an abbreviated MR protocol combining short TI inversion recovery (STIR), turbo-spin-echo (TSE)-T2 sequences, a pre-contrast T1, and a single intermediate (3 minutes after contrast injection) post-contrast T1 sequence for characterizing breast lesions. **Materials and Methods:** A total of 470 patients underwent breast MR examination for screening, problem solving, or preoperative staging. Two experienced radiologists evaluated both standard and abbreviated protocols in consensus. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy for both protocols were calculated (with the histological findings and 6-month ultrasound follow-up as the reference standard) and compared with the McNemar test. The post-processing and interpretation times for the MR images were compared with the paired *t* test. **Results:** In 177 of 470 (38%) patients, the MR sequences detected 185 breast lesions. Standard and abbreviated protocols obtained sensitivity, specificity, diagnostic accuracy, PPV, and NPV values respectively of 92%, 92%, 92%, 68%, and 98% and of 89%, 91%, 91%, 64%, and 98% with no statistically significant difference ($P < .0001$). The mean post-processing and interpretation time were, respectively, $7 \pm 1$ minutes and $6 \pm 3.2$ minutes for the standard protocol and $1 \pm 1.2$ minutes and $2 \pm 1.2$ minutes for the abbreviated protocol, with a statistically significant difference ($P < .01$). **Conclusion:** An abbreviated combined MR protocol represents a time-saving tool for radiologists and patients with the same diagnostic potential as the standard protocol in patients undergoing breast MRI for screening, problem solving, or preoperative staging.

*Clinical Breast Cancer*, Vol. 16, No. 3, 207-11 
**Keywords:** Abbreviated protocol, Breast, Breast lesions, Carcinoma, MRI

# PROTOCOLLO ABBREVIATO




*Moschetta M et al. Clinical Breast Cancer 2016; DOI* 10.1016/j.clbc.2016.02.008

# TEMPI DI ACQUISIZIONE

| Abbreviated combined MR protocol | Standard MR protocol |
|---|---|
| STIR – Acquisition time 4 minutes | STIR – Acquisition time 4 minutes |
| TSE T2 – Acquisition time 3 minutes | TSE T2 – Acquisition time 3 minutes |
| Pre-contrast THRIVE – Acquisition time 1.3 minutes | Pre-contrast THRIVE – Acquisition time 1.3 minutes |
| 1 Post- contrast THRIVE – Acquisition time 1.3 minutes (3 minutes after gadolinium injection) | 5 Post-contrast THRIVE sequences – Acquisition time 7.3 minutes |
| Total acquisition time (10 minutes) | Total acquisition time (16 minutes) |

*Moschetta M et al. Clinical Breast Cancer 2016; DOI* 10.1016/j.clbc.2016.02.008

# STAGING

# STAGING LOCOREGIONALE

- CUTE
- MUSCOLO PETTORALE
- LN ASCELLARI
- LN MAMMARI INTERNI

BJR|Open https://doi.org/10.1259/bjro.20220002

Received: 17 January 2022 | Revised: 01 May 2022 | Accepted: 04 May 2022 | Published online: 26 May 2022

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Galati F, Rizzo V, Trimboli RM, Kripa E, Maroncelli R, Pediconi F. MRI as a biomarker for breast cancer diagnosis and prognosis. *BJR Open* (2022) 10.1259/bjro.20220002.

REVIEW ARTICLE

# MRI as a biomarker for breast cancer diagnosis and prognosis

[1]FRANCESCA GALATI, MD PhD, [1]VERONICA RIZZO, MD, [2]RUBINA MANUELA TRIMBOLI, MD, PhD, [1]ENDI KRIPA, MD, [1]ROBERTO MARONCELLI, MD and [1]FEDERICA PEDICONI, MD

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[2]Humanitas Clinical and Research Center – IRCCS, Via Manzoni 56 - 20089, Rozzano (MI), Italy

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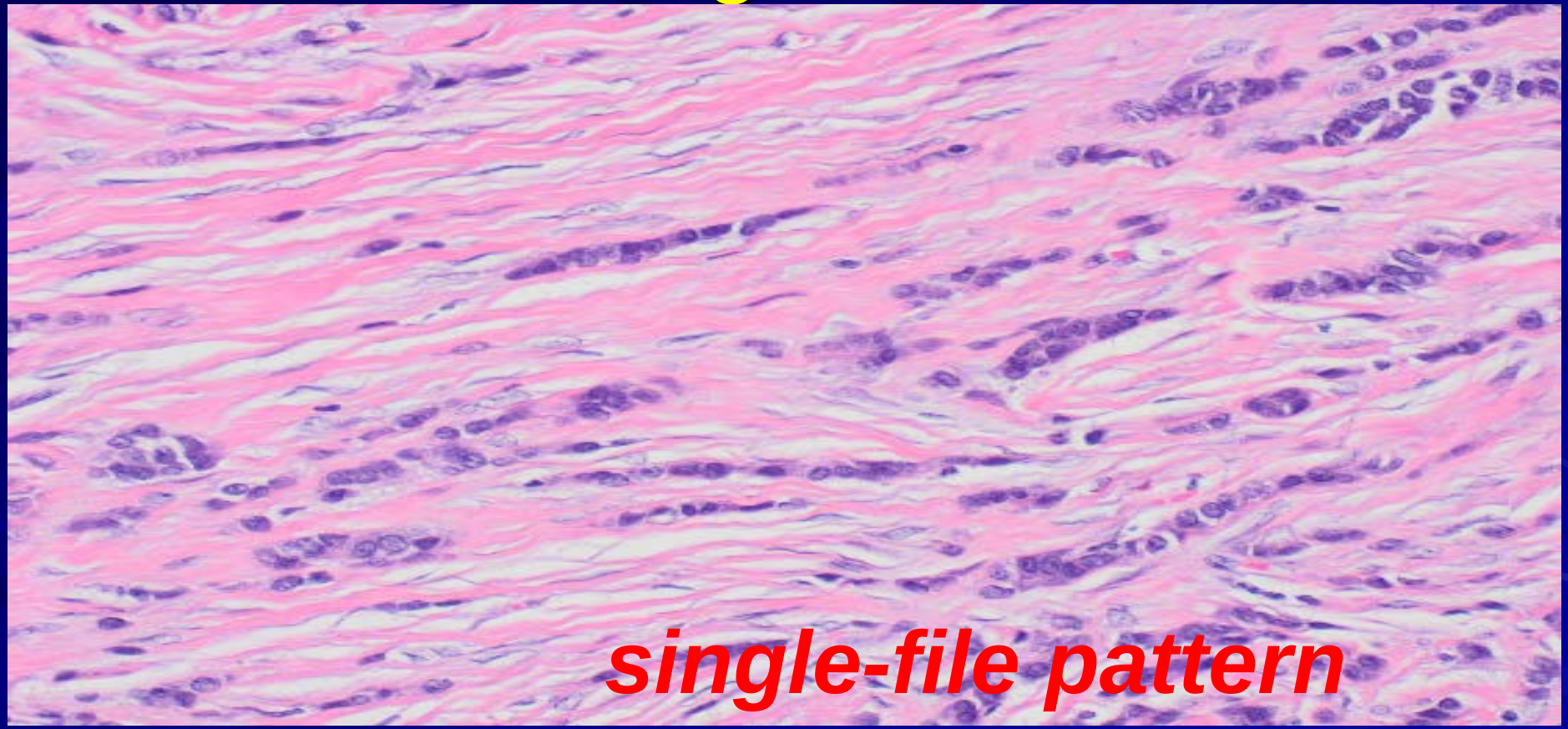
E-mail: *francesca.galati@uniroma1.it*

## CONCLUSIONS

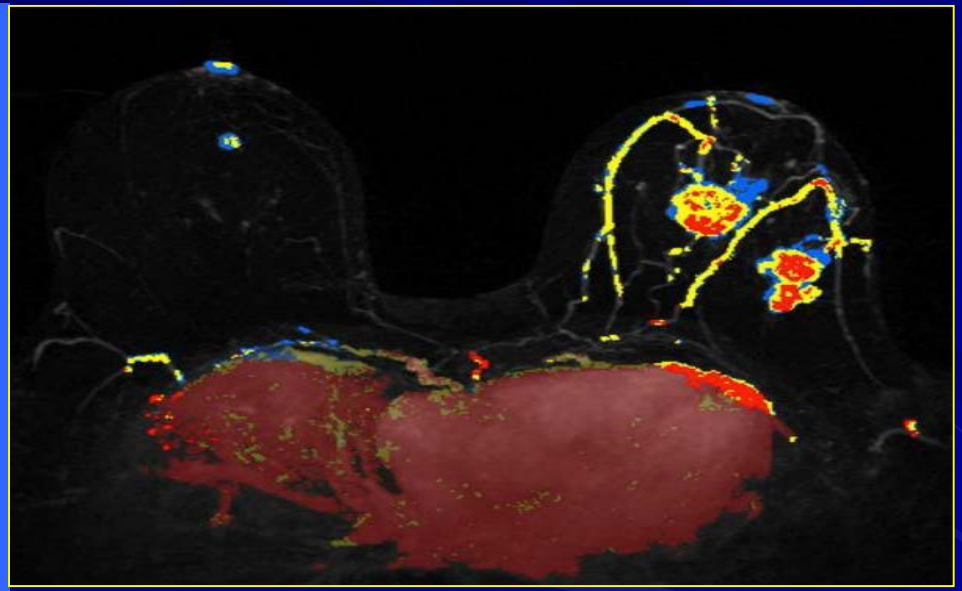
Breast MRI may act as a diagnostic and prognostic tool to improve BC management through the extraction of a plenty of functional cancer parameters serving as imaging biomarkers. The intrinsic multiparametric nature of MRI provides specific information to visualize and quantify the functional processes of cancer development and progression, in order to improve detection and characterization of breast lesions, monitoring and prediction of response to therapy, and differentiation of biological BC subtypes. Moreover MRI images, due to their complex information content, are a fertile ground for AI applications. These may improve the integration of imaging biomarkers in clinical decision-making through the building of accessible predictive integrated models aiming at individualized medicine.

# Pathologic features

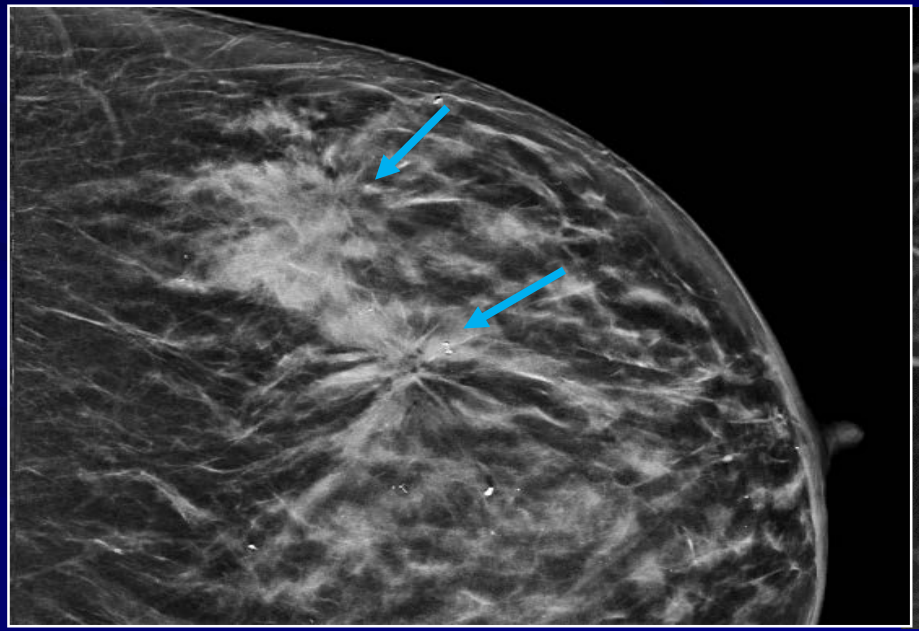


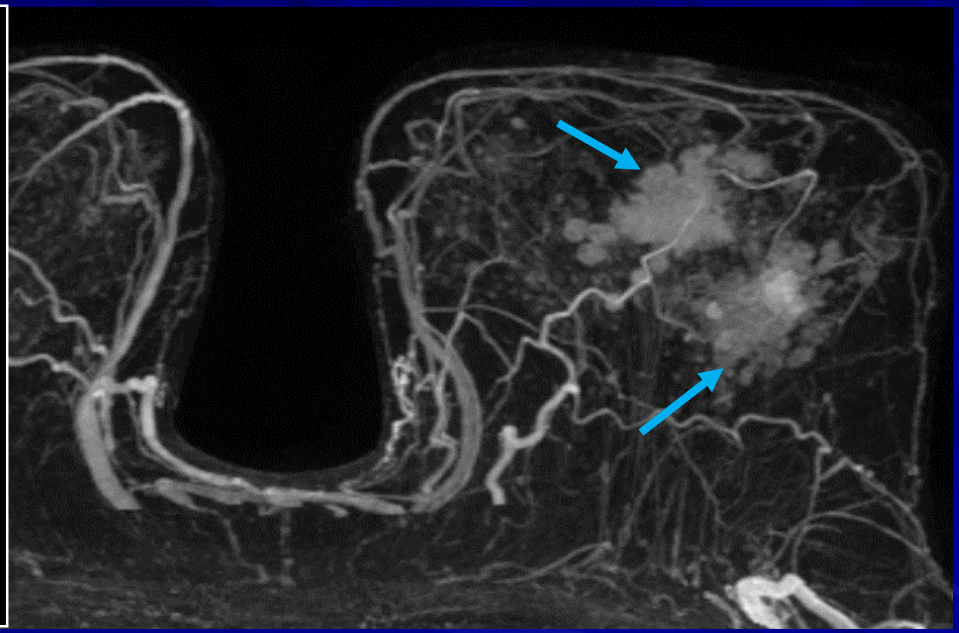
# MRI

- **MRI SENSITIVITY: 93%-95%**
- **SUPERIOR TO MX AND US FOR LOCAL STAGING** (MULTIFOCALITY, MULTICENTRICITY, TUMOR SIZE)
- **AFFECT CLINICAL TREATMENT IN 50% OF PATIENTS WITH ILC, LEADING TO CHANGES IN SURGICAL TREATMENT IN 28% OF CASES.**

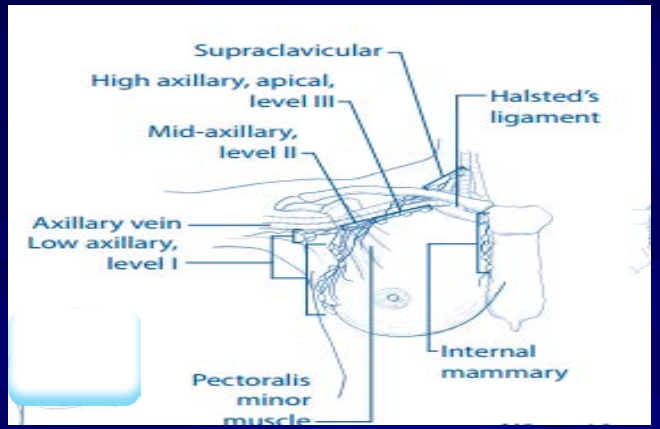


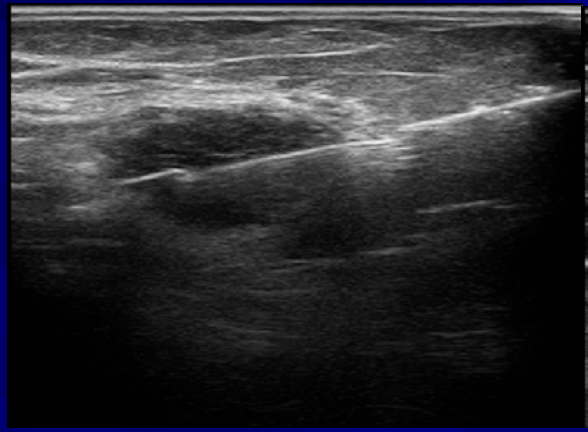
RadioGraphics FUNDAMENTALS

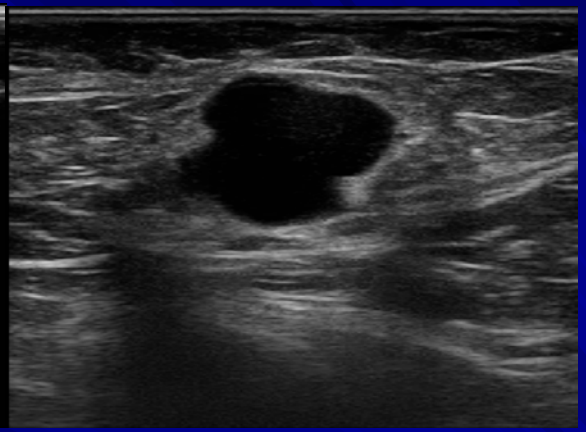


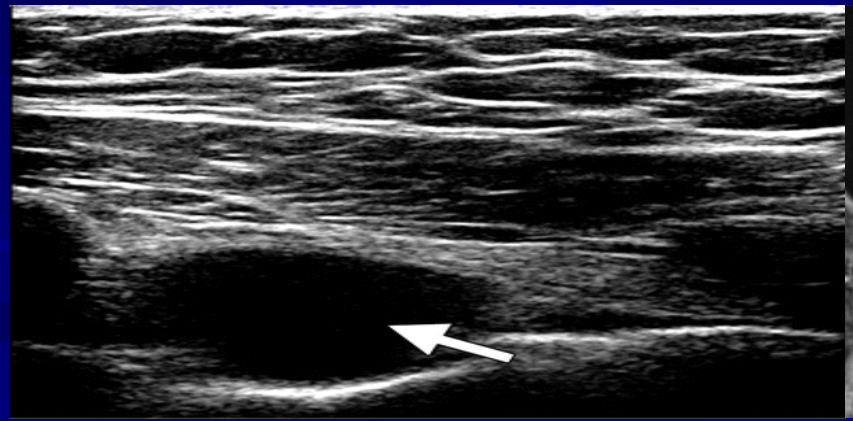


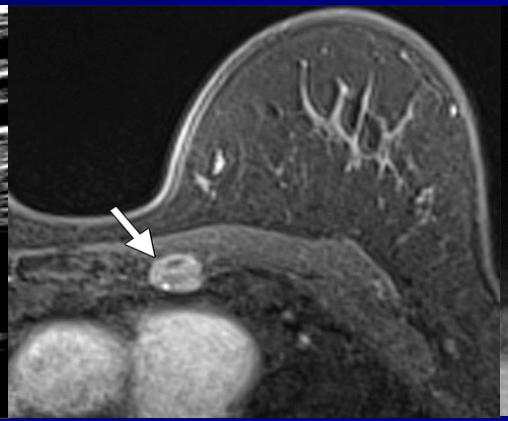
***Multifocal*** *disease, more extensive at MRI*

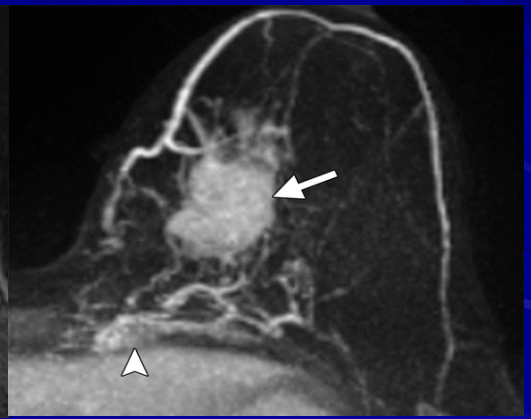

Supraclavicular
High axillary, apical, level III
Halsted's ligament
Mid-axillary, level II
Axillary vein
Low axillary, level I
Internal mammary
Pectoralis minor muscle

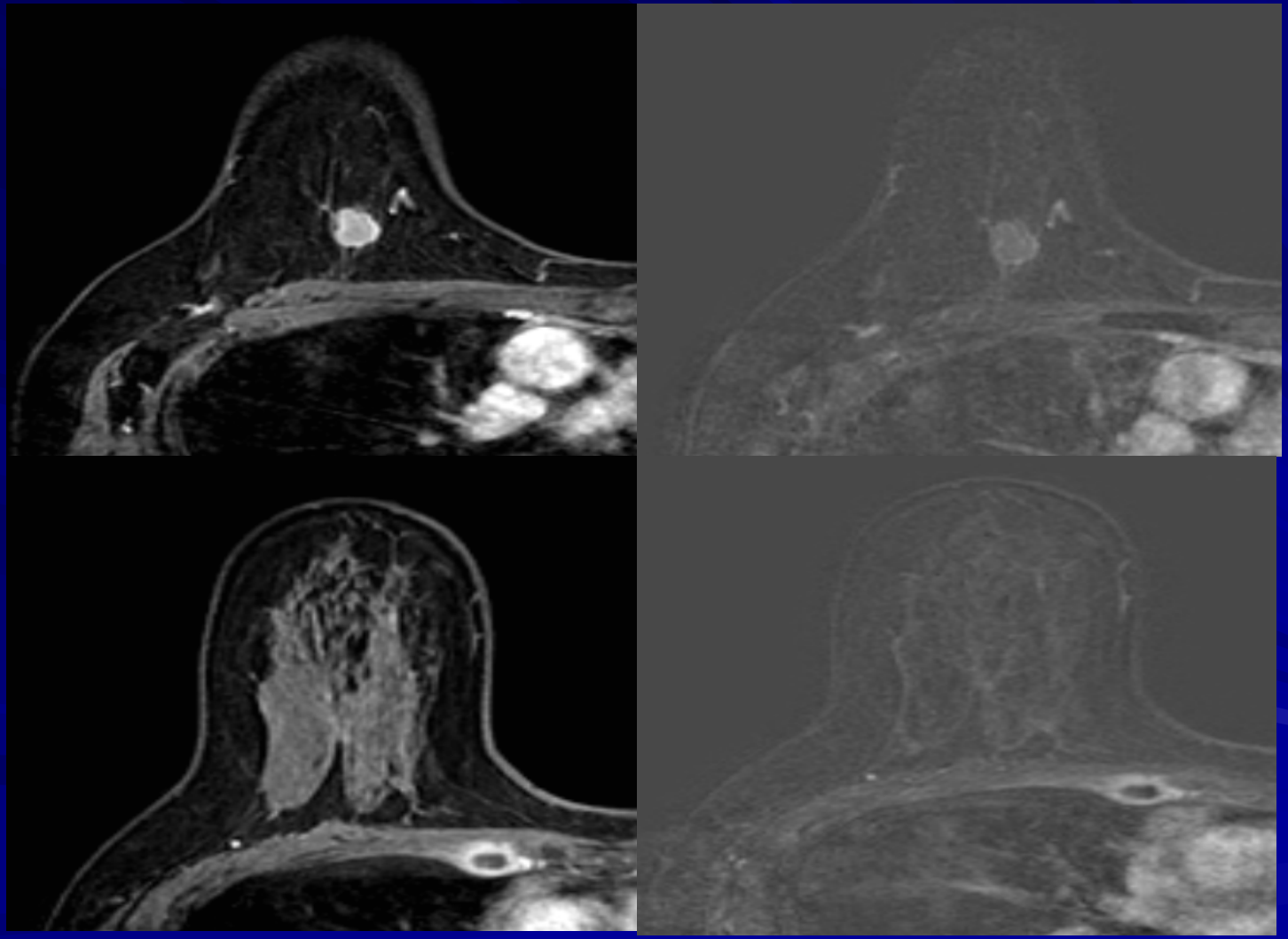




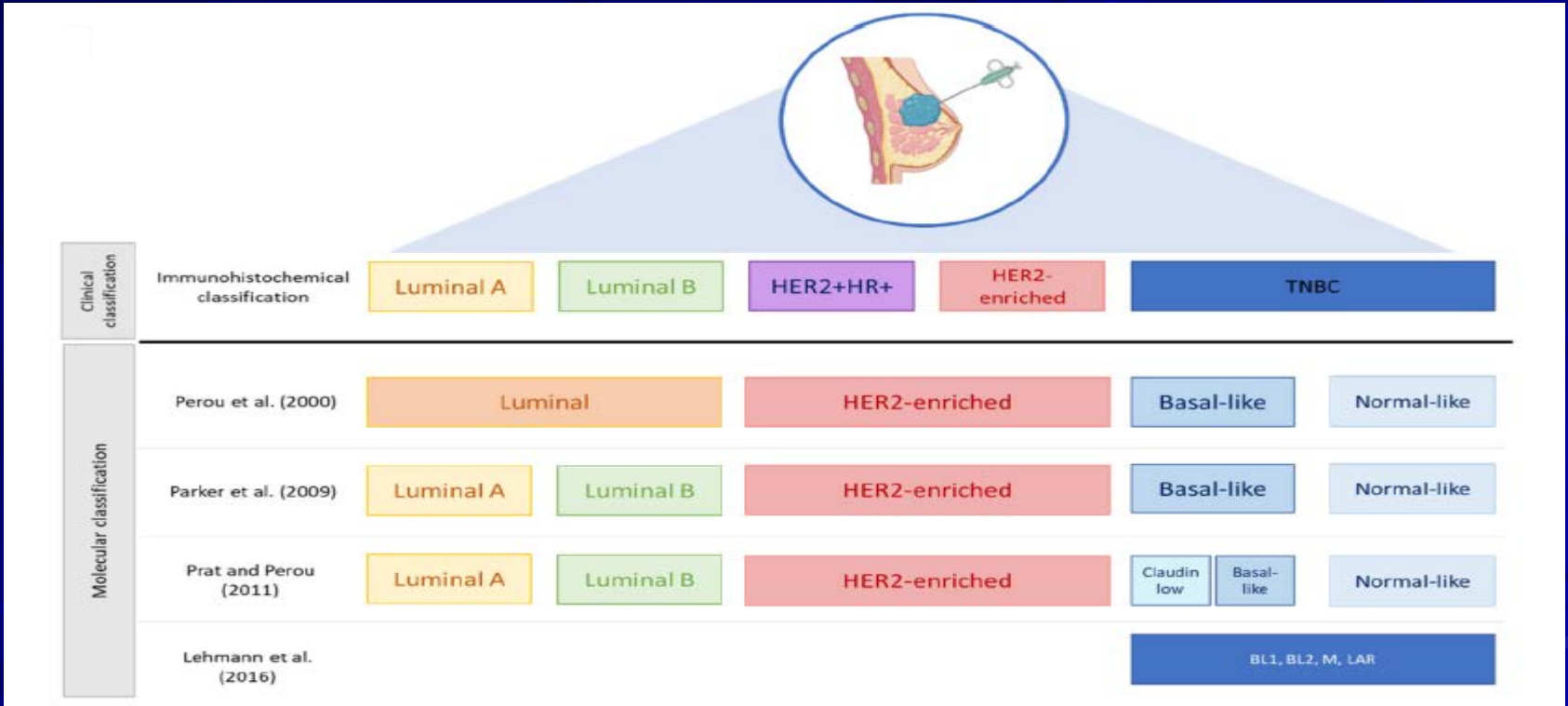








# NACT




Cancers **2022, 14, 3876. https://doi.org/10.3390/cancers14163876**

# IMAGING

- MX –DBT
- US
- ABUS
- MRI
- CEM
- PET-CT

frontiers | Frontiers in Oncology

REVIEW
published: 20 May 2022
doi: 10.3389/fonc.2022.816297

Check for updates

# Advances in Imaging in Evaluating the Efficacy of Neoadjuvant Chemotherapy for Breast Cancer

*Xianshu Kong[1†], Qian Zhang[1†], Xuemei Wu[1], Tianning Zou[1], Jiajun Duan[1], Shujie Song[2], Jianyun Nie[1], Chu Tao[1], Mi Tang[2], Maohua Wang[3], Jieya Zou[1], Yu Xie[4], Zhenhui Li[4*] and Zhen Li[1*]*

| Number | Study | Number of patients | Research type | Examination | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| 1 | Keune et al. (6) | 192 | retrospective study | US/MG | 45.8/54.2 | 93.8/86.3 |
| 2 | Skarping et al. (15) | 202 | prospective study | MG/US/DBT | 65/62/50 | 81/81/91 |
| 3 | Iotti et al. (22) | 46 | prospective study | CESM/MRI | 100/87 | 84/60 |
| 4 | Patel et al. (23) | 65 | prospective study | CESM/MRI | 95/95 | 66.7/68.9 |
| 5 | Barra et al. (24) | 33 | prospective study | CESM/MRI | 76/92 | 87.5/75 |
| 6 | ElSaid et al. (25) | 21 | prospective study | CESM | 40 | 91 |
| 7 | Xing et al. (26) | 111 | retrospective study | CESM | 75-81.25 | 72.15-51.90 |
| 8 | Amioka et al. (31) | 63 | prospective study | CEUS/MRI/PET-CT | 95.7/69.6/100 | 77.5/85/52.5 |
| 9 | Huang et al. (34) | 143 | prospective study | CEUS | 78.6 | 74.5 |
| 10 | Wang et al. (38) | 290 | prospective study | ABUS | 85.7-88.1 | 81.5-85.1 |
| 11 | Fernandes et al. (43) | 92 | prospective study | SE | 84 | 85 |
| 12 | Katyan et al. (44) | 86 | prospective study | SE | 97.7-77.8 | 68.7-100 |
| 13 | Jing et al. (45) | 62 | prospective study | SWE | 72.92 | 85.71 |
| 14 | Lee et al. (46) | 71 | prospective study | US/SWE | 72.1/83.6 | 50/80 |
| 15 | Maier et al. (48) | 134 | prospective study | SWE | 79.6 | 58.6 |
| 16 | Sannachi et al. (49) | 30 | prospective study | QUS | 82 | 100 |
| 17 | Yu et al. (52) | 20 | prospective study | OPTI-MUS | 76.9 | 71.4-85.7 |
| 18 | Altoe et al. (54) | 40 | prospective study | OPTI-MUS | 86.7 | 68.4 |
| 19 | Tran et al. (55) | 22 | prospective study | QUS+OPTI-MUS | 64.3-100 | 62.5-100 |
| 20 | Bouzon et al. (58) | 91 | prospective study | MRI | 75 | 78.57 |
| 21 | Cheng et al. (66) | 969 | meta-analysis | DCE-MRI | 80 | 84 |
| 22 | Zheng et al. (70) | 63 | prospective study | DCE-MRI | 66.8-75.0 | 60.0-66.7 |
| 23 | Fukuda et al. (72) | 265 | prospective study | DCE-MRI | 43.2 | 97.7 |
| 24 | Zhu et al. (78) | 64 | prospective study | DWI-MRI | 91.67 | 87.5 |
| 25 | Richard et al. (79) | 118 | retrospective study | DWI-MRI | 100 | 38 |
| 26 | Liu et al. (81) | 176 | retrospective study | DWI-MRI | 62.5-75 | 82.61-97.36 |
| 27 | Che et al. (87) | 36 | prospective study | IVIM-MRI | 100 | 73.7 |
| 28 | Jagannathan et al. (103) | 67 | prospective study | $^{1}$H-MRS | 78 | 86 |
| 29 | Tozaki et al. (104) | 34 | prospective study | $^{1}$H-MRS | / | / |
| 30 | Bayoumi et al. (108) | 47 | prospective study | $^{1}$H-MRS+DCE-MRI | 75 | 97.1 |
| 31 | Liu et al. (110) | 382 | meta-analysis | (18)F-PETCT/MRI | 86/65 | 72/88 |
| 32 | Li et al. (111) | 1193 | meta-analysis | MRI/PETCT | 0.88/0.77 | 0.69/0.78 |
| 33 | Sheikhbahaei et al. (112) | 595 | meta-analysis | MRI/PETCT | 0.88/0.71 | 0.55/0.77 |
| 34 | Schwarz-Dose et al. (113) | 87 | prospective study | PETCT | 69-73 | 63 |
| 35 | Akimoto et al. (114) | 130 | prospective study | (18)F-PET/CT | 79.3 | 53.1 |

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# Magnetic resonance imaging in breast cancer management in the context of neo-adjuvant chemotherapy

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ARTICLE INFO

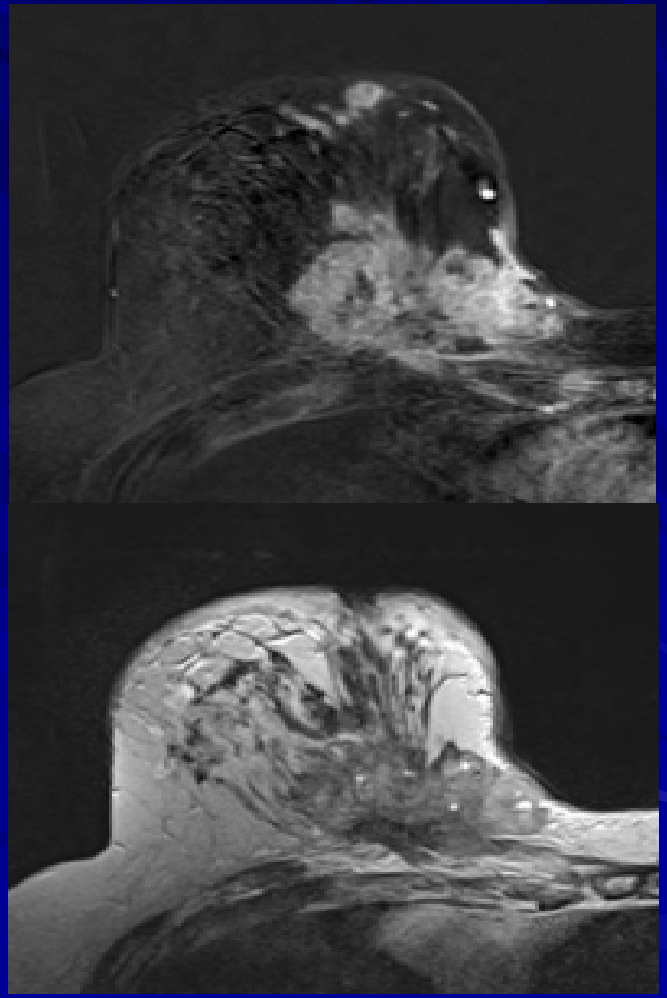
*Keywords:*
MRI
Neo-adjuvant chemotherapy
Breast cancer

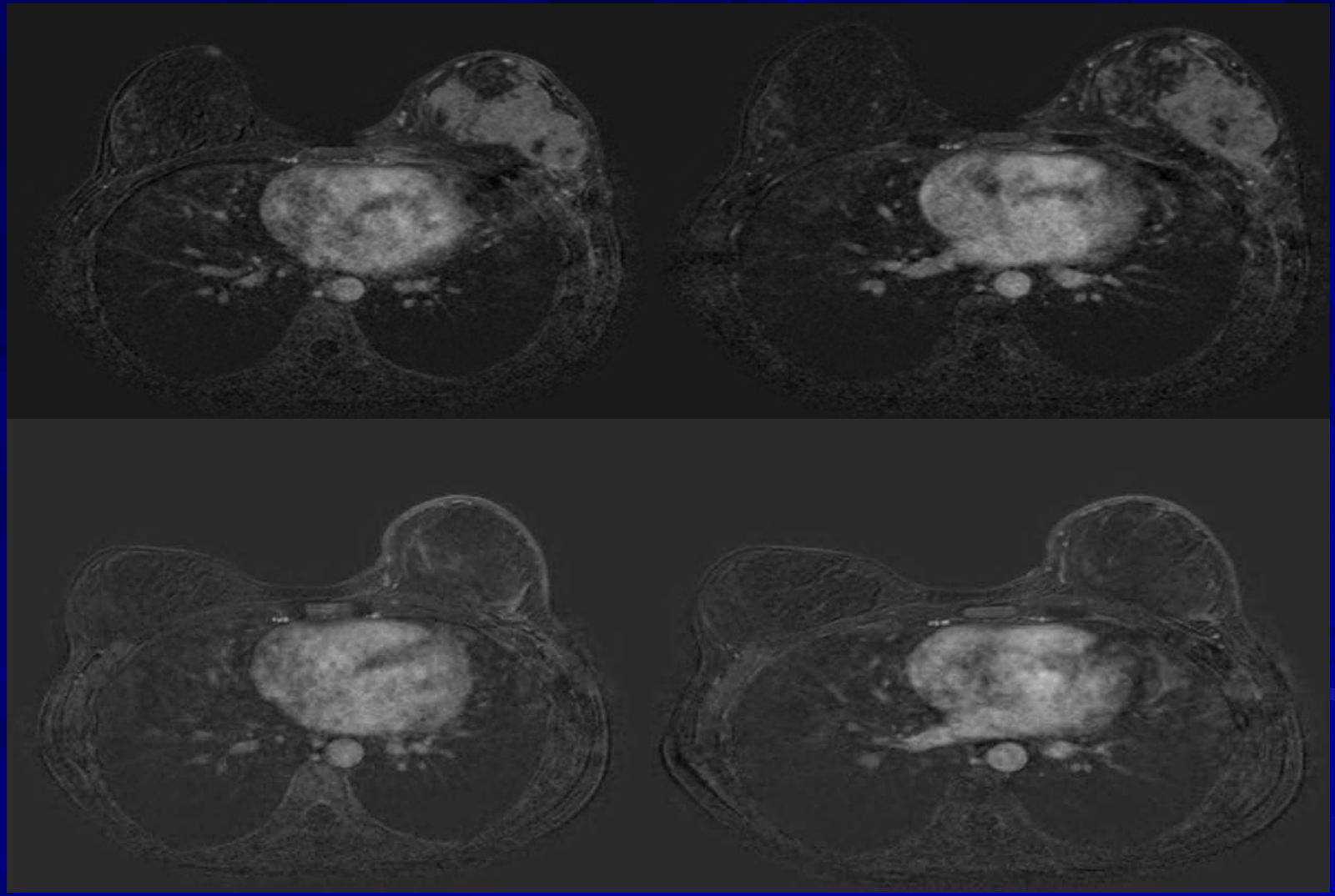
ABSTRACT

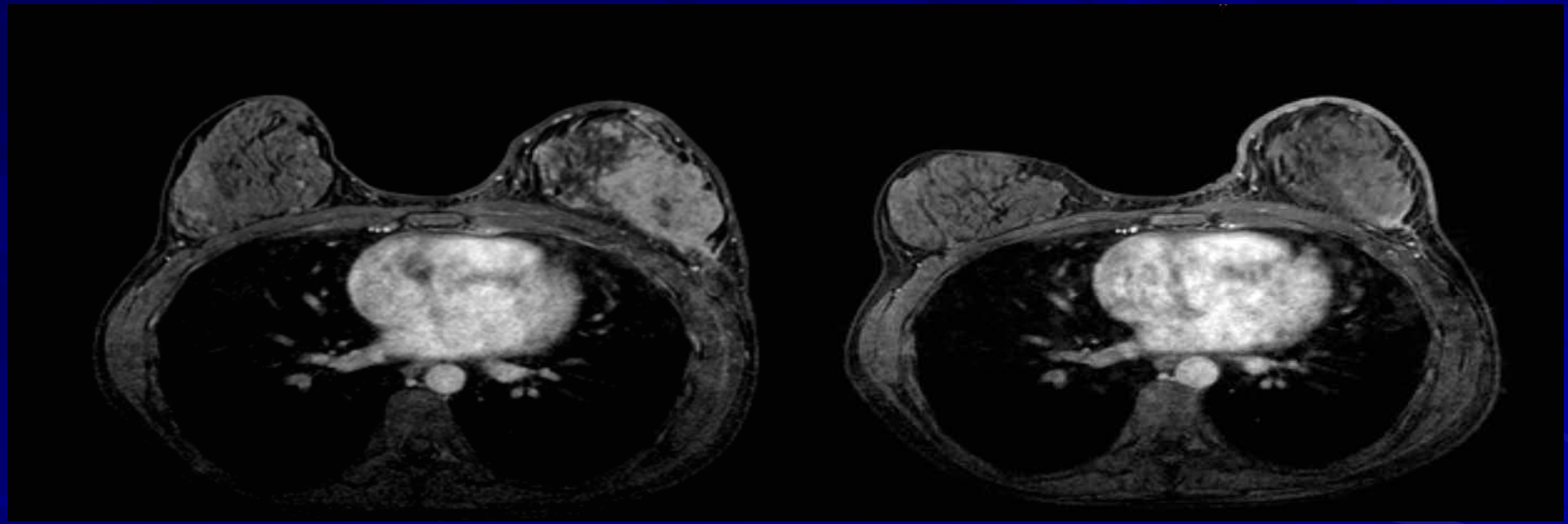
This review discusses the clinical applications of magnetic resonance imaging (MRI) for the assessment of neo-adjuvant chemotherapy (NAC) indication, axillary lymph node status, preNAC cancer prognosis, early and intermediate response to NAC, and post-NAC residual disease in patients with breast cancer. Contrast-enhanced MRI with analysis of the tumor morphological features and qualitative enhancement kinetics must be considered as the standard method for pre-NAC breast cancer staging and post-NAC residual disease assessment. Diffusion-weighted imaging (DWI) is easy to perform and may increase the specificity of breast MRI for tumor staging, and also for the assessment of tumor multifocality and multicentricity and lymph node status. It also provides an ancillary added value in the early and post-NAC response evaluation. Changes in the functional tumor volume are the main criterion for the early response analysis. Other MRI methods, such as quantitative perfusion analysis, MR spectroscopy and texture analysis, are still under study.

# RM

- SIZE
- MULTIFOCAL DISEASE
- MULTICENTRIC DISEASE
- CONTROLATERAL
- PECTORAL
- SKIN







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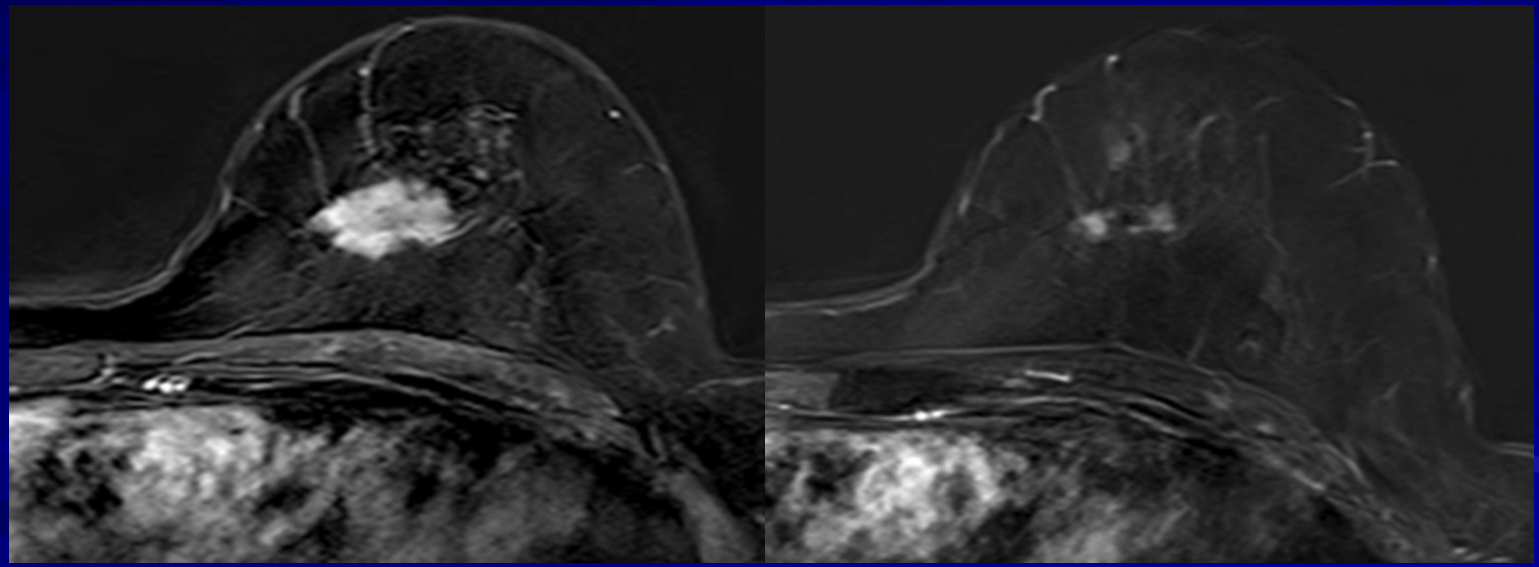

# CEM

REVIEWS AND COMMENTARY · REVIEW

Radiology

## Contrast-enhanced Mammography: State of the Art

*Maxine S. Jochelson, MD* • *Marc B. I. Lobbes, MD, PhD*

From the Department of Radiology, Breast Imaging Service, Memorial Sloan-Kettering Cancer Center, 1275 York Ave, New York, NY 10065 (M.S.J.); Department of Medical Imaging, Zuyderland Medical Center, Sittard-Geleen, the Netherlands (M.B.I.L.); Department of Radiology and Nuclear Medicine, Maastricht University Medical Center, Maastricht, the Netherlands (M.B.I.L.); and GROW School for Oncology and Developmental Biology, Maastricht University, Maastricht, the Netherlands (M.B.I.L.). Received May 5, 2020; revision requested June 9; revision received October 9; accepted October 13. **Address correspondence to** M.S.J. (e-mail: *jochelsm@mskcc.org*).

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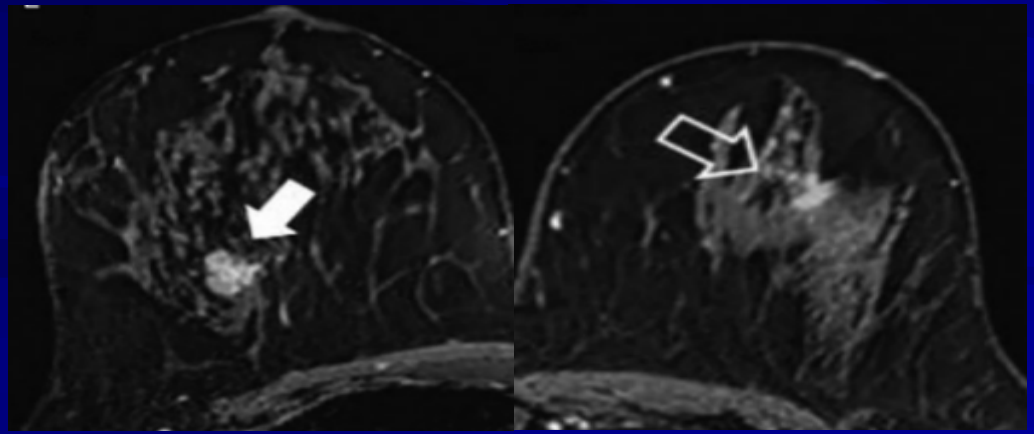
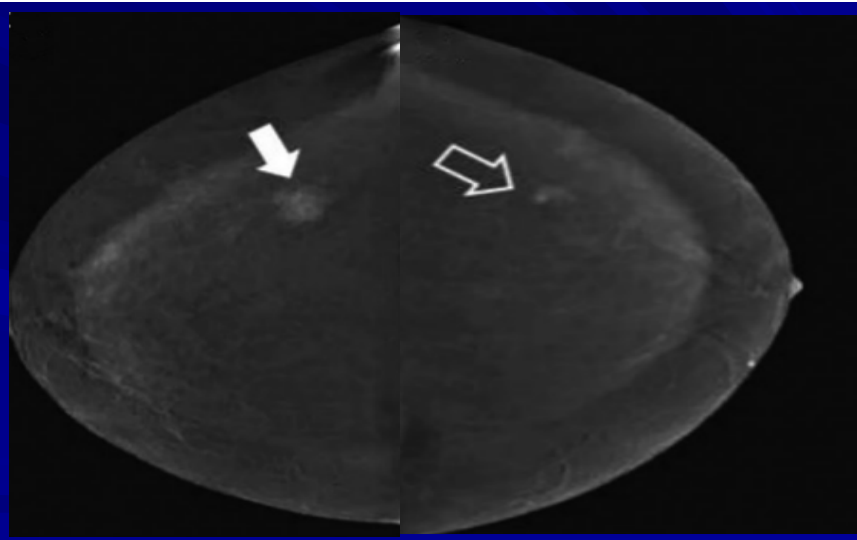
Conflicts of interest are listed at the end of this article.

**Radiology 2021; 299:36–48** • **https://doi.org/10.1148/radiol.2021201948** • **Content code: BR**

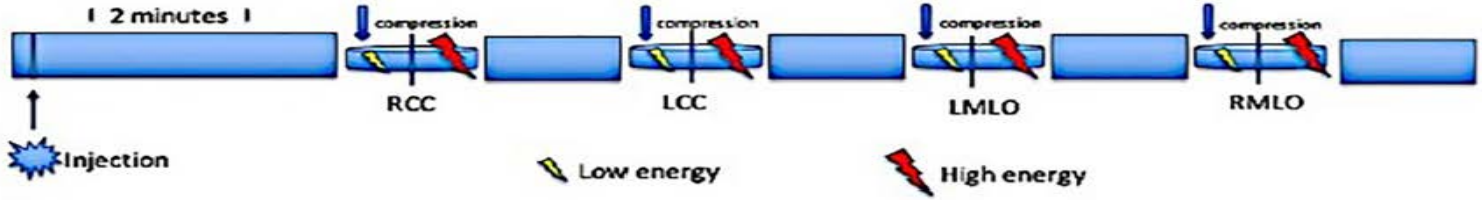


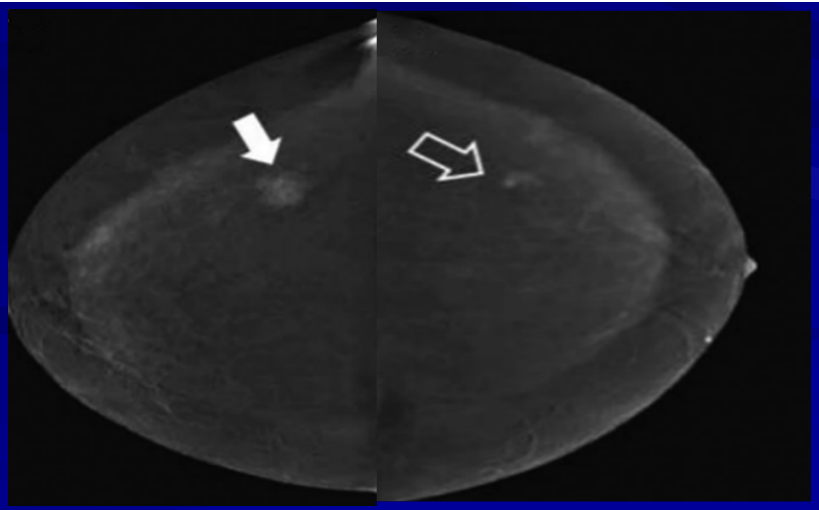


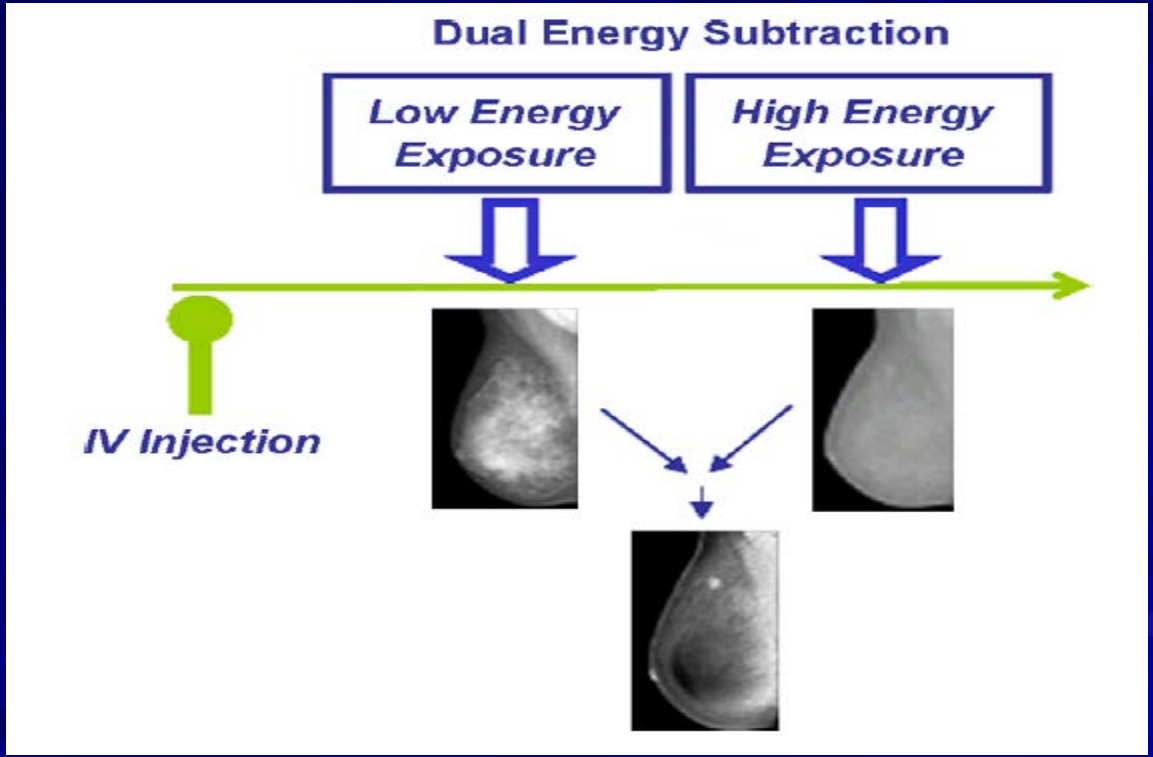
# CEM

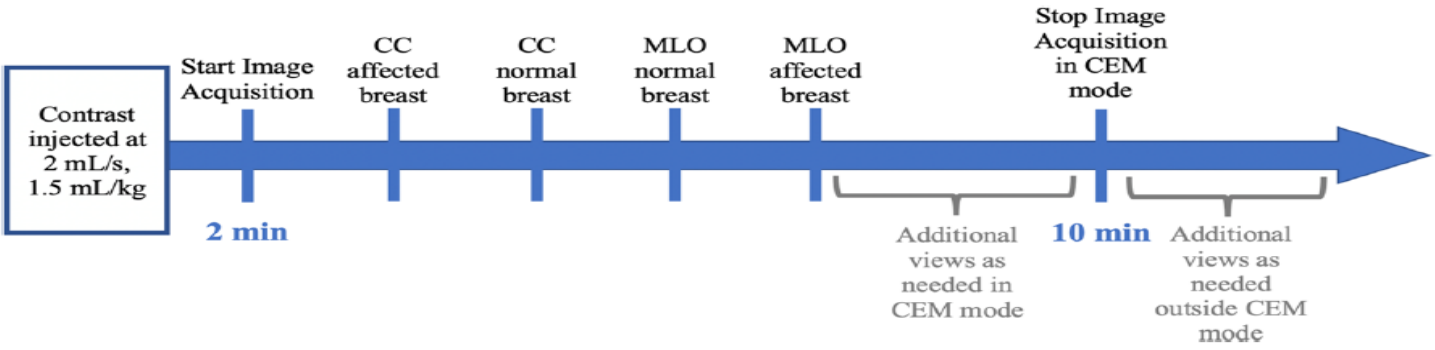


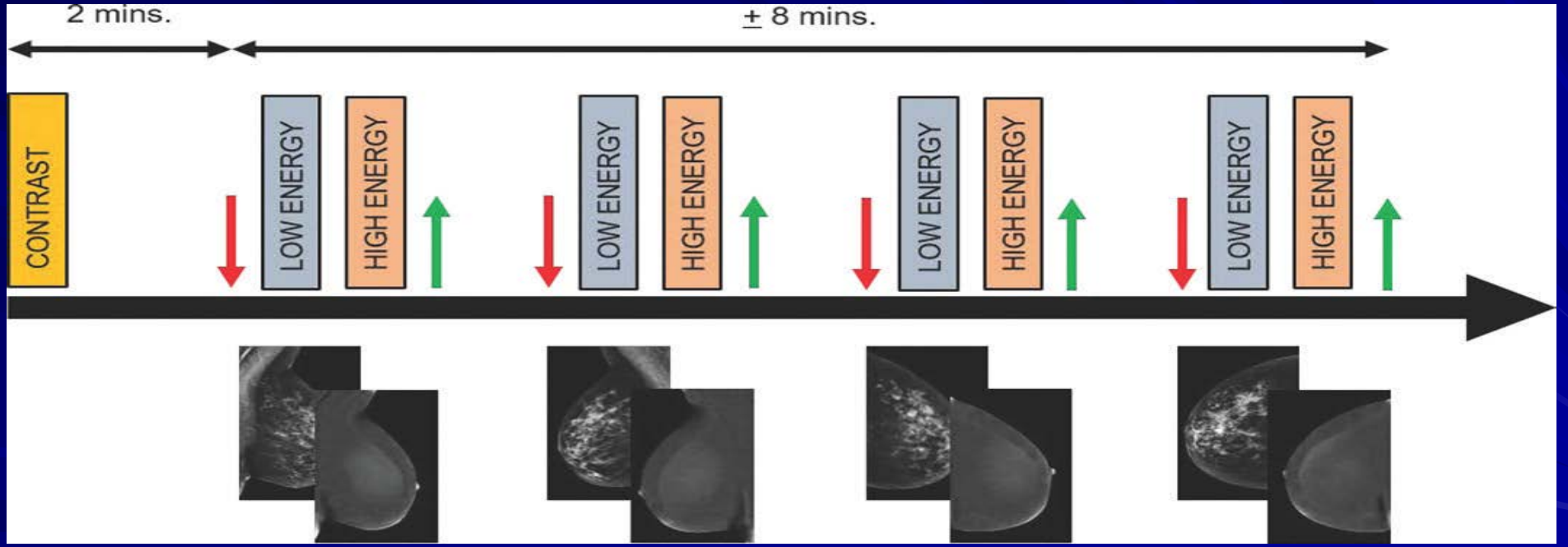
Clinical Imaging 71 (2021) 126–135

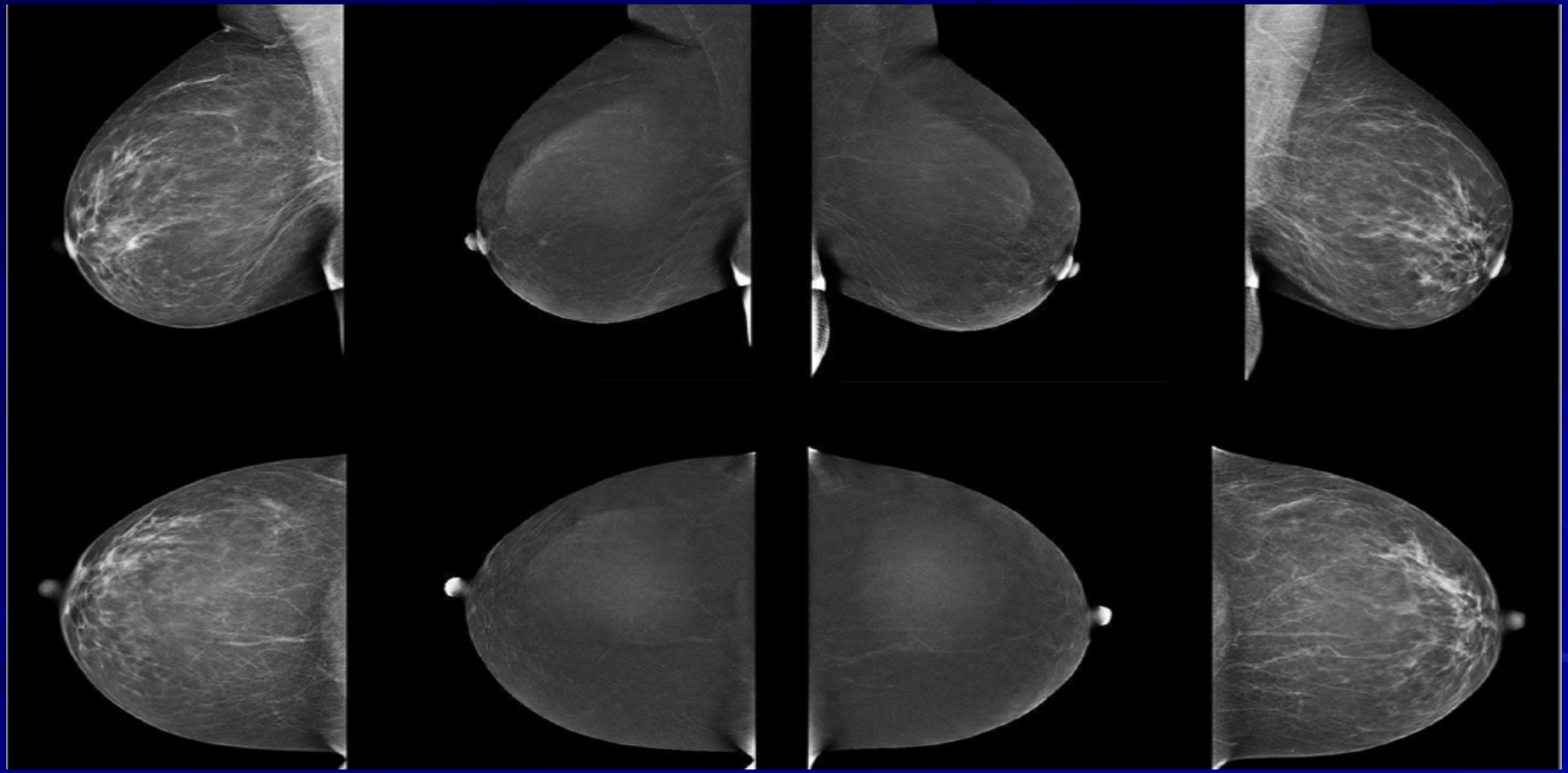



Dual Energy Subtraction
Low Energy Exposure
High Energy Exposure
IV Injection


Contrast injected at 2 mL/s, 1.5 mL/kg
Start Image Acquisition
CC affected breast
CC normal breast
MLO normal breast
MLO affected breast
Stop Image Acquisition in CEM mode
2 min
Additional views as needed in CEM mode
10 min
Additional views as needed outside CEM mode


2 mins.
± 8 mins.
CONTRAST
LOW ENERGY
HIGH ENERGY
LOW ENERGY
HIGH ENERGY
LOW ENERGY
HIGH ENERGY
LOW ENERGY
HIGH ENERGY



Yang *et al. Cancer Imaging* (2023) 23:10
https://doi.org/10.1186/s40644-023-00526-1

Cancer Imaging

REVIEW Open Access

# Contrast enhanced mammography: focus on frequently encountered benign and malignant diagnoses

Mindy L. Yang[1,2], Chandni Bhimani[1,3], Robyn Roth[1] and Pauline Germaine[1*]

**Table 1** Current Indications for CEM

| |
|---|
| High-risk screening (not an FDA approved indication but under investigation) |
| Supplementation to screening mammography in heterogeneously dense and extremely dense breast parenchyma in accordance with local state regulations, usually in the setting of dense breast clinic |
| Further assessment of inconclusive findings on diagnostic workup |
| Assessment of palpable abnormality with negative prior workup |
| Staging of known breast cancer, particularly in patients with contraindications to MRI |
| Assessment of response to chemotherapy, especially in patients with contraindications to MRI |

European Journal of Radiology 69 (2009) 34–42

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# Contrast-enhanced digital mammography

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[c] Department of Medicine, Institut Gustave-Roussy, 39, rue Camille Desmoulins, 94805 Villejuif Cedex, France

# CONTRAST ENHANCED MAMMOGRAPHY (CEM)

(A supplement to ACR BI-RADS® Mammography 2013)

## 2022

Carol H. Lee, MD, Chair

Jordana Phillips, MD
Janice S. Sung, MD
John M. Lewin, MD
Mary S. Newell, MD

Documento SIRM 2022

# Statement sull'uso della Mammografia con MdC (CEM) in Italia

## A cura della Sezione di Studio di Senologia della Società Italiana di Radiologia Medica e Interventistica

Massimo Calabrese, Stefania Montemezzi, Gianfranco Paride Scaperrotta, Valentina Iotti,

Maria Adele Marino, Giuseppe Di Giulio, Marco Moschetta, Giulia Bicchierai

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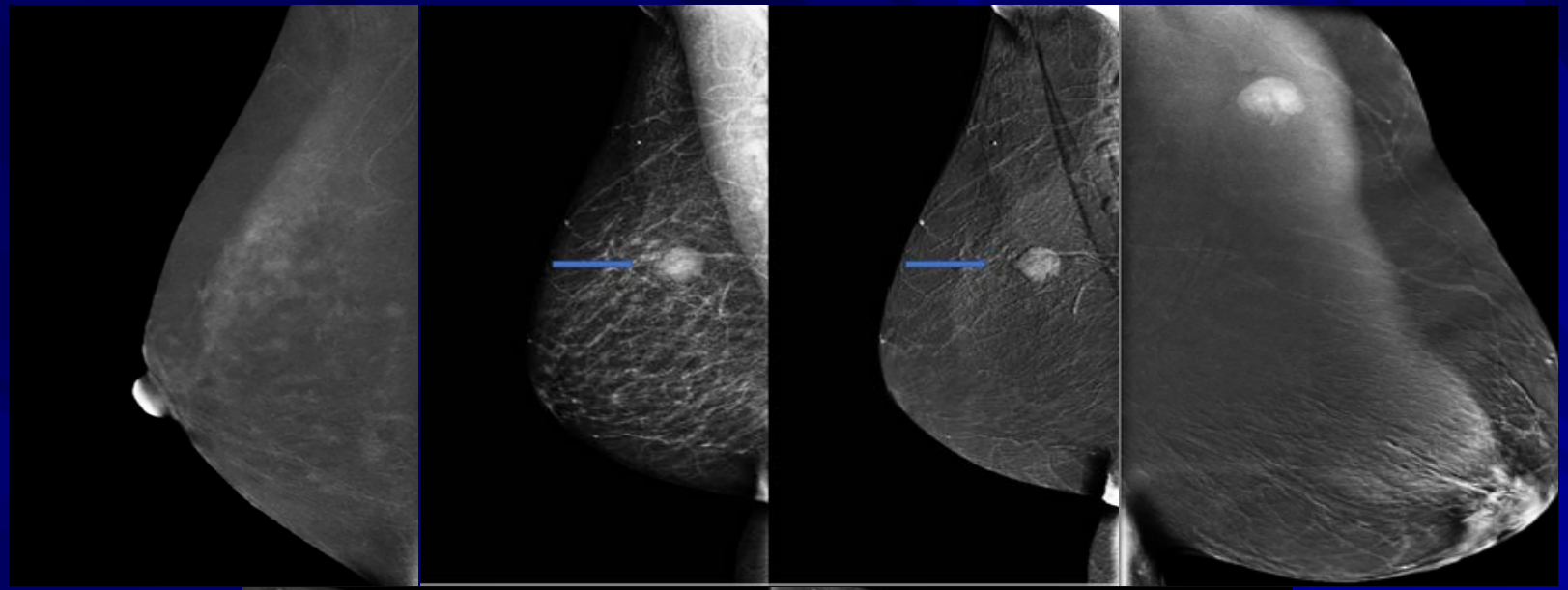
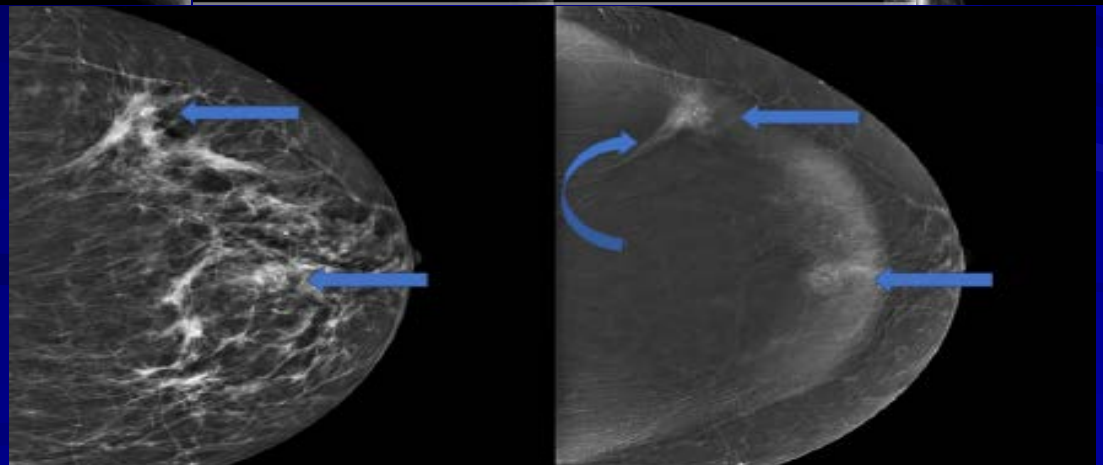
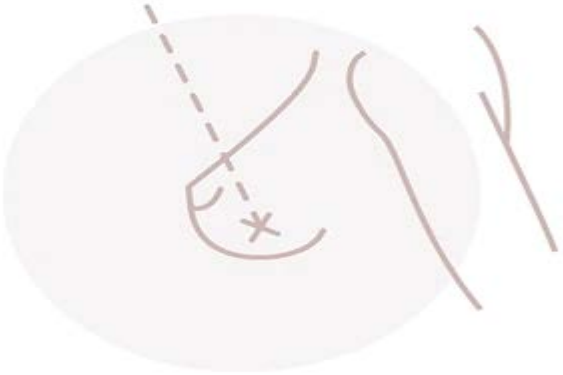
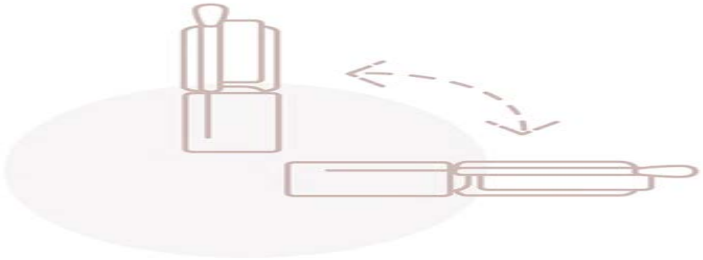
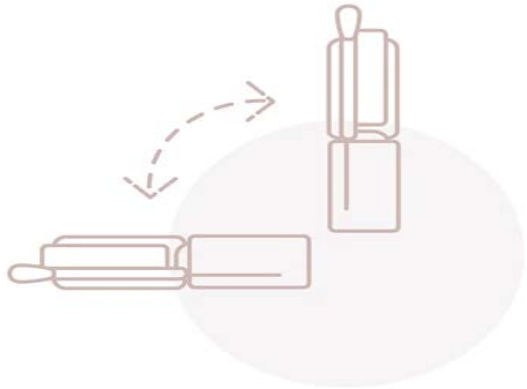
# CEM

- STAGING
- PROBLEM SOLVING
- MEDIO E ALTO RISCHIO
- PZ SINTOMATICHE
- VALUTAZIONE RISPOSTA A NAC
- FOLLOW UP PZ OPERATE
- GESTIONE B3 VALUTAZIONE VAE







European Radiology (2023) 33:417–428
https://doi.org/10.1007/s00330-022-09021-w

BREAST

# Contrast-enhanced mammography-guided biopsy: technical feasibility and first outcomes

R. Alcantara[1] · M. Posso[2] · M. Pitarch[1] · N. Arenas[1] · B. Ejarque[1] · V. Iotti[3] · G. Besutti[3,4]

Received: 2 March 2022 / Revised: 23 May 2022 / Accepted: 30 June 2022 / Published online: 27 July 2022


**Abstract**

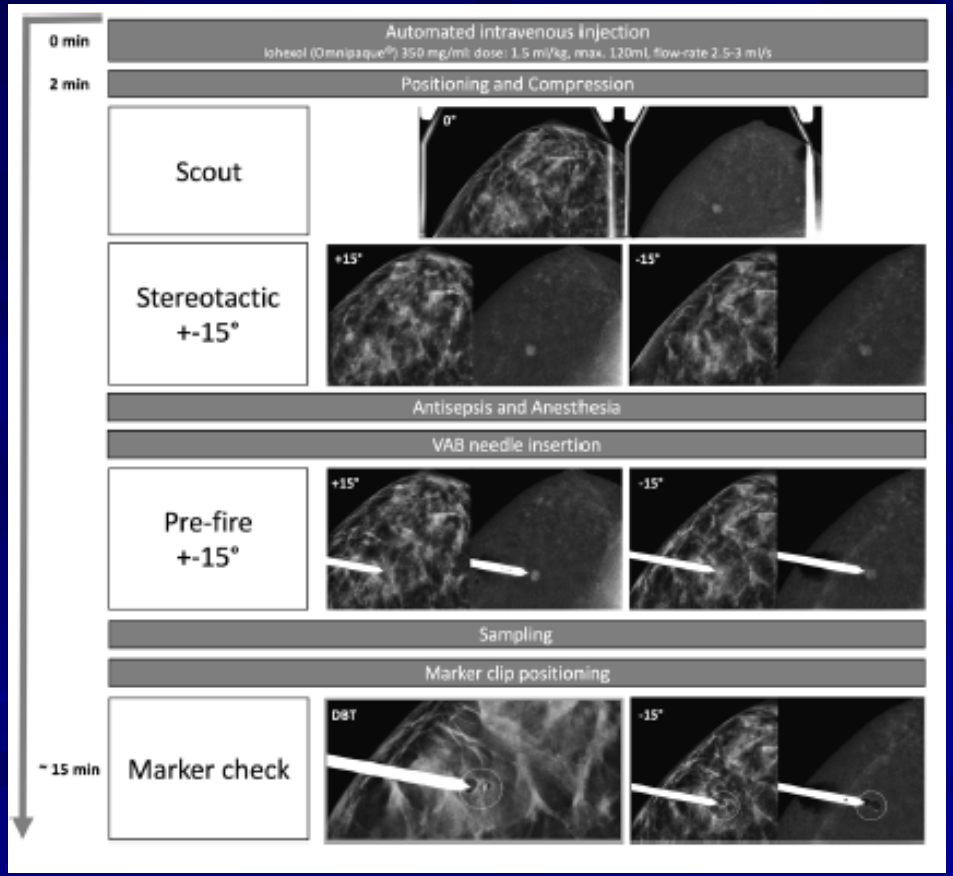
**Objectives** To evaluate the feasibility of contrast-enhanced mammography (CEM)-guided biopsy at Hospital del Mar, a Spanish university hospital.

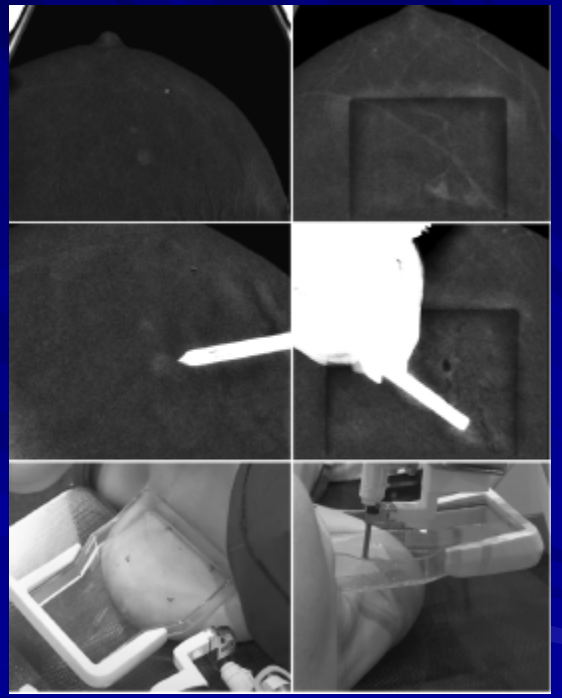
**Methods** We retrospectively reviewed all consecutive women with a suspicious enhancing finding eligible for CEM-guided biopsy, who were prospectively enrolled in a pre-marketing clinical validation and feasibility study (October 2019 to September 2021). CEM-guided biopsy is a stereotactic-based procedure that, by using intravenous iodinated contrast media administration and dual-energy acquisition, provides localisation of enhancing lesions. All the biopsies were performed using a vacuum-assisted device. We collected procedural characteristics (patient position and type of approach), and histopathological results. Feasibility endpoints included success (visualisation of the enhancing lesion, post-procedural biopsy changes and clip placement), procedural time, number of scout acquisitions and complications.

**Results** A total of 66 suspicious enhancing lesions (18.0% foci, 44.0% mass, 38.0% non-mass enhancement; median size 8.5 mm) in 64 patients (median age 59 years, mostly minimal [48.4%] or mild [32.8%] background parenchymal enhancement) were referred for CEM-guided biopsy in the study period. The success rate was 63/66 (95.4%). Amongst successful procedures, patients were most frequently seated (52/63, 82.5%) and the preferred approach was horizontal (48/63, 76.2%). Median total time per procedure was 15 min. Median number of acquisitions needed before targeting was 2 (range 1–4). Complications consisted of hematoma (17/63, 27%) and vasovagal reaction (2/63, 3.2%). At histology, the malignancy rate was 25/63 (39.7%).

**Conclusion** In this first patient series, CEM-guided breast biopsy was feasible, with success and complication rates similar to those previously reported for magnetic resonance guidance.

Key points


0 min
Automated intravenous injection
Iohexol (Omnipaque®) 350 mg/ml; dose: 1.5 ml/kg, max. 120ml, flow-rate 2.5-3 ml/s
2 min
Positioning and Compression
Scout
0°
Stereotactic +-15°
+15°
-15°
Antisepsis and Anesthesia
VAB needle insertion
Pre-fire +-15°
+15°
-15°
Sampling
Marker clip positioning
~ 15 min
Marker check
DBT
-15°



# RM vs CEM

- Staging preoperatorio
- Screening alto rischio
- NAC
- Impianti protesici
- CUP Syndrome
- Mammella operata
- Problem solving
- Mammella secernente

**Switch from MRI to CEM biopsy**

| INDICAZIONI | RM | CEM |
|---|---|---|
| ENHANCEMENT CUTANEO | VISIBILE | NON VISIBILE |
| LINFONODI | MAGGIORE COPERTURA ANATOMICA | NON SEMPRE VISIBILI<br>NO MAMMARIA INTERNA |
| SPECIFICITA' | MENO SPECIFICA | PIU' SPECIFICA |
| CONTROINDICAZIONI | PACEMAKERS, OBESITA', ETA', CLAUSTROFOBIA | IMPIANTI PROTESICI, INSUFFICIENZA RENALE |
| DIFFUSION | SI | NESSUNA INFORMAZIONE |
| RADIOMICA – AI - PREDIZIONE | SI | SI |
| RX | NO | SI |
| POST-PROCESSING | PIU' COMPLESSO – MAGGIOR NUMERO DI DATI | NON NECESSARIO – NESSUNA INFORMAZIONE CU CINETICA |
| ARTEFATTI | COMUNI MENO EVITABILI | MENO FREQUENTI EVITABILI |
| SISTEMI DI BIOPSIA | SI | SI |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