Optimizing post-treatment imaging surveillance in breast cancer survivors

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Breasts are a common area of operation; anatomical changes in the breasts caused by various surgical procedures change the findings on breast imaging. As some of these changes may look similar to malignant changes, it is important to understand which surgical changes cause changes on imaging. The purpose of postoperative breast imaging is to assess the postoperative outcome and complications, detect recurrent tumors at the operation site, and demonstrate other interval changes. I will discuss the normal and abnormal breast imaging findings after breast surgery.

1. Excisional biopsy

Excisional biopsy is a technique in which the lesion is completely removed, with or without the surrounding tissues. The initial changes after biopsy are air collection, hematoma, fluid collection, edema, etc. The long-term changes are architectural distortion and shortening of the subcutaneous fibrosis and Cooper’s ligaments.

2. Breast-conserving surgery

Breast-conserving surgery is the primary treatment of most breast cancers in stages 1 and 2, and in recent years, about 60-70% of breast cancer patients have undergone breast-conservation surgery. It involves resection of the tumor mass, including some surrounding normal tissues, and preservation of the nipple and other breast tissues. Breast-conserving surgery and radiotherapy affect the mammographic findings, and even without recurrence, there may be various findings, such as increased density, structural distortion, skin thickening, and calcification. Some positive changes after surgery and radiotherapy may be similar to the malignant findings on imaging and pathologic examination.

3. Total mastectomy

Total mastectomy includes radical or modified radical mastectomy, skin sparing mastectomy, and nipple sparing mastectomy. Modified radical mastectomy is the most common and is performed for cancers in the breast or axilla without invasion of the pectoralis major muscle or fascia. Ultrasonography shows that the mastectomy site has four layers of skin, subcutaneous fat, pectoral muscle, ribs, and chest wall. The findings on breast imaging after mastectomy include fluid collection, skin thickening, and mass. To assess recurrence, the lymph nodes, upper and lower parts of the clavicle, axilla, and internal mammary area are examined. The most common sites of local recurrence are the chest wall and supraclavicular lymph nodes.

4. Reconstructive procedures

Breast reconstruction after mastectomy has been performed for many years for the psychological and cosmetic satisfaction of patients. There are various methods, such as using tissue expanders, implants, and autologous myocutaneous flaps. Therefore, the imaging findings are diverse. The normal mammographic findings of the breasts restored using a transverse rectus abdominis myocutaneous flap are mainly fatty appearance and various densities because of the muscle component and postoperative scarring. The problem is recurrence. The mechanism of tumor recurrence is tumor seeding at the surgical site, cancer development in the remaining breast epithelial cells, and embolization of cells within the disrupted lymphatic vessels. The imaging findings of recurrent cancer should be differentiated from fat necrosis. The most common finding of recurrent cancer is a mass with or without calcification, which is similar to that of the primary cancer.
5. Reduction mammoplasty

The most common method is to fix the nipple areolar complex with an incision connected to the areola at the 6 o’clock position in the inframammary fold. The nipple areolar complex moves upward. The breast is removed; the upper part of the breast is moved down; the mammary parenchyma is mainly located in the lower part of the breast; the scar and parenchymal band are visible and may be accompanied with fat necrosis.

6. Augmented mammoplasty

There are various methods of augmentation, including silicone and saline implant insertions and cosmetic injections. Depending on the method, various changes are observed on breast imaging. Most of them are normal postoperative changes, but some of them are associated with malignancy or complications.

Understanding the surgical procedures and accompanying normal and abnormal postoperative changes on radiologic imaging is important to differentiate between benign postoperative conditions and tumor recurrence.

References

1. Women with a personal history of breast cancer (PHBC)
   - Sustained long-term risk of experiencing another breast cancer (BC) diagnosis
   - Second BC
     1) Another primary BC in the treated conserved breast
     2) Local recurrence in the treated conserved breast
     3) Contralateral BC

2. Rates of second breast cancer
   - In women with early-stage invasive BC treated with breast conservation and adjuvant radiation: 0.4-1%
   - Contralateral BC rates: 0.6% per year
   - Cumulative risk of a second BC at 5 years in cohorts with a history of stage 0-II first BC: approximately 1% per 1 year

3. Guideline Recommendation for women with PHBC Guideline MG Ultrasound MRI
   - American Cancer Society 2016 Annual Not specified
   - Not recommended American College of Radiology (ACR) 2014 Annual Based on risk assessment (if MRI is contraindicated) Based on risk assessment National Comprehensive Cancer Network (NCCN) 2016 Annual Not specified Recommends against routine MRI unless patients meet high-risk criteria European Society for Medical Oncology (ESMO) 2015 Annual May be used (young patients with dense breasts and genetic history) National Institute for Health and Care Excellence (NICE) 2014 Annual Not recommended Not recommended

4. Comparison of surveillance modalities in 754 women with a history of breast-conserving therapy at age < 50 years Diagnostic accuracy MG Ultrasound MRI
   - Cancer detection rate per 1000 screens 4.4 5.3 7.3
   - Sensitivity 53% 65% 88%
   - Specificity 96% 90% 90%
   - Recall rate 4.4% 10.1% 10.7%
   - Biopsy rate 0.5% 1.1% 2.5%

5. Breast MRI for women with PHBC
   1) Pros: detects more second BCs (MRI more so than ultrasound)
   2) Cons: also add substantially to the burden of recall and false-positive screening

6. Recommendation of breast imaging surveillance in women with PHBC
   1) Women without risk: Annual mammography + breast clinical examination
   2) Women with BRCA gene mutations or estimated ≥ 20% life-time risk: adjunct MRI
   3) Women with increased risk* of an interval second BC following negative mammography surveillance: consider adjunctive imaging such as ultrasound or MRI

   - Increased risk: Age < 50 at screen or age ≤ 40 at first cancer diagnosis/ Received breast conserving surgery without radiation/ First breast cancer was an interval cancer at screening/ Markedly dense breasts (BI-RADS density category 4)/ More than one of these risk factors for having interval second cancer: breast density BI-RADS category 3; first cancer high-grade invasive or symptomatic presentation, received breast conserving surgery for first cancer

References
1. Houssami N, Cho N. Screening women with a personal history of breast cancer: overview of the evidence on breast imaging surveillance. Ultrasonography


8. Cho N, Han W, Han BK, Bae MS, Ko ES, Nam SJ, et al. Breast cancer screening with mammography plus ultrasonography or magnetic resonance imaging in women 50 years or younger at diagnosis and treated with breast conservation therapy. JAMA Oncol 2017;3:1495-1502
Early detection of breast cancer through x-ray mammography (MG) has been shown to reduce mortality; however, the method is limited by a decreased sensitivity and specificity particularly in young patients and women with radiographically dense breasts due to tissue overlying and masking tumours or architectural distortions.

Since nearly hundred years contrast agent is now used in imaging. The first big step for contrast use in breast imaging was the introduction of breast MRI in the 80s. Nevertheless, imaging of breast tumors using X-ray and iodinated contrast agents started much earlier. But due to the missing digital technique, the subtraction of the images persists challenging. With the introduction of full-field digital detectors end of the 90's, tomosynthetic techniques and also contrast enhanced breast imaging with mammography came back into focus, as the development of these further technical methods enabled us to overcome these limitations.

Consequently we could use tomosynthesis to reduce the overlying structures and CEM, after some technical adaptations of the mammography machines to increase sensitivity due to higher contrast and better lesion delineation than mammography alone especially if mammography is limited particularly in women with radiographically dense breasts, due to a reduced contrast difference between breast tumors and surrounding breast tissue.

In this talk I will present the history and background of tomosynthesis, CEM and CET, the technique of acquiring the images and patient preparation. Potential advantages and disadvantages will be indicated and a sample of clinical cases will be presented to illustrate how tomosynthesis and CEM contributes to the detection of lesions.

In addition I will present clinical performance results of tomosynthesis esp. in the screening setting and of CESM versus MRI, mammography and ultrasound. The potential of this technique in imaging the response to neoadjuvant chemotherapy will be elaborated. The role in detection of recurrence during follow up examinations after breast conserving therapy will be addressed as well.

Potential advantages and disadvantages will be indicated and a sample of clinical cases will be presented to illustrate how the different techniques contribute to the detection of lesions and how it can be used in routine workup.
With the advance in medical technology and widely available breast imaging modalities in practice, indications for, intervention methods, and management after intervention has changed remarkably during the recent decade. During this session, we will briefly go over the newly introduced intervention methods for image-detected breast abnormalities, discuss ways to select the most cost-effective biopsy method for patients with imaging-detected breast abnormalities, and management for patients diagnosed with high risk lesions on biopsy in the current era.
Understanding B3 lesions

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1. Core Biopsy Reporting Guidelines (1)
   1. B1 (normal breast tissue/inadequate sample),
      B2 (benign tissue),
      B3 (benign but of uncertain malignant potential)
      B4 (suspicious for malignancy)
      B5 (malignant)

   Types of B3 lesions (lesion of uncertain malignant potential) (1)

   1. This category mainly consists of lesions which may provide benign histology on core biopsy but are known to show heterogeneity or to have an increased risk (albeit low) of associated malignancy.

   Atypical epithelial proliferations (atypical ductal hyperplasia, ADH)

   Included under a B3 classification are atypical epithelial hyperplastic lesions in which a uniform population of cells arranged in an appropriate manner involves one space or partially involves two or more spaces. These appearances should be sufficiently structured to raise the possibility of low grade DCIS but insufficient in the tissue available to fulfill the diagnostic criteria. There is a range of severity from those which are insufficient for a definite diagnosis of DCIS but highly suspicious to those which only show a minor degree of atypia, normally architectural, which requires further assessment, and judgement of appropriate categorization B3 or B4 is required.

   The definition of atypical ductal hyperplasia is derived from surgical resection specimens and relies on a combination of histological, morphological and size extent criteria. For this reason, accurate diagnosis of ADH is not possible on core biopsy. It has, however, been shown that core biopsy samples which include atypical epithelial proliferative foci of insufficient extent for classification as DCIS may, on subsequent surgical resection, form part of an established in situ neoplastic lesion with or without associated invasion. This view is based on several studies that describe the subsequent surgical diagnoses in cases described as ADH in non-operative core biopsy. In over 50% of cores, surgical excision biopsy has shown either in situ or invasive carcinoma. This is not surprising as ADH is basically defined as an epithelial proliferation showing the features of low grade DCIS, but in fewer than two spaces or less than 3 mm in diameter. The limited tissue sampling that can be undertaken by core biopsy guns (often by stereotactic methods for foci of microcalcification) may thus provide insufficient material for definitive diagnosis of low grade DCIS if only a few spaces are obtained. In these cases a diagnosis of atypical intraductal epithelial proliferation and a classification of B3 of uncertain malignant potential or B4 suspicious of malignancy should be made dependent on the severity and extent of the lesion.

   1. Lobular neoplasia

   A small cell regular epithelial proliferation within lobules that is considered by the pathologist to represent lobular neoplasia (ALH/LCIS) should be classified as B3. In common with ADH, the criteria used to distinguish between atypical lobular hyperplasia (ALH) and lobular carcinoma in situ (LCIS) are derived from surgically resected tissue. Accurate distinction may not be possible in a limited core biopsy sample. This process does not have the same management implications as a diagnosis of DCIS or invasive malignancy and does not per se require therapeutic excision. Lobular neoplasia is, however, most frequently a coincidental finding in a core biopsy from a screen detected lesion, and multidisciplinary discussion is essential, as the abnormality identified radiologically may not be represented. These cases must be managed cautiously.
On occasion it may be impossible to classify a small cell epithelial proliferation in lobules and/or ducts as either lobular neoplasia or low-grade DCIS, and in these circumstances a numerically higher category (B4 or B5) is prudent and should be considered.

Phyllodes tumor

1. Fibroadenomatoid lesions with cellular stroma, stromal overgrowth and possibly some mitotic activity suggesting a phyllodes tumour should also be designated B3. Thus, the presence of a cellular stroma within a fibroepithelial lesion should prompt a search for other features that may aid in discrimination from a fibroadenoma. In practice, however, this distinction is often impossible, and careful appraisal of the entire clinical picture will usually allow appropriate management to be undertaken.

1. Papillary lesions

Papillary lesions may also show significant intralesimal heterogeneity, and the limited sampling achieved with core biopsy may miss areas of in situ cancer. Thus, the majority of these lesions should also be designated B3 of uncertain malignant potential. On rare occasions when a small lesion has been very widely sampled and submitted for pathological examination, a benign B2 classification may be considered. Conversely, when a sample of a papillary lesion in a core biopsy shows atypia, for example strongly suspicious of papillary carcinoma in situ, a B4 designation may occasionally be more appropriate.

1. Radial scar/complex sclerosing lesion

Biopsies which show features of a radial scar/complex sclerosing lesion such as areas of hyalinization, elastosis or tubular entrapment with epithelial proliferation should be categorized as B3. Although still a matter of debate, many authorities believe that a proportion of these lesions are associated with malignancy. Thus, unless the sclerosing lesion is very widely sampled, the process should be designated B3 as the presence of an associated area of DCIS or invasive carcinoma cannot be excluded.

1) Malignancy rates of B3 lesions (2)
1. Management recommendation of the Zurich Consensus Conference on B3 lesions (3,4)

Diagnosis made by CNB (core-needle biopsy) Diagnosis made by VAB (vacuum-assisted biopsy) ADH (atypical ductal hyperplasia) OE (open surgical excision) OE. Surveillance can be considered in a few special situations after discussion at the multidisciplinary meeting FEA (flat epithelial atypia) VAB to complete removal of the lesion visible in any imaging method Surveillance in justified if the radiological lesion has been removed LN (classical lobular neoplasia) OE or VAB (remove US-visible lesion) OE or high-risk surveillance of the radiological lesion has been removed PL (papillary lesions) Remove by VAB PT (phyllodes tumours) OE. Free margins in borderline and malignant PTs Follow-up in completely excised benign PTs surveillance is justified RS (radial scars) VAB or OE of visible lesion Surveillance is justified if the radiological lesion has been removed VAB usually the lesion should not exceed 2.5 cm in diameter. For the larger lesions, OE is preferred LN only classical type. LN pleomorphic, LIN 3, LN extended, and LN with necrosis are defined as B5a lesions and should undergo OE, PL with atypia: Such a lesion should not be classified as papilloma, but rather as FEA or ADH according to the type of atypia found.

References

SS 28 BR-01 16:00

Diagnostic accuracy of contrast enhanced spectral mammography for the assessment of malignancy in BI-RADS 3 and 4 mammographic findings

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PURPOSE: To assess the performance of CESM to diagnose breast cancer in BI-RADS 3, 4 findings detected by mammography.

MATERIALS AND METHODS: Between April 2018 and April 2019, 200 women with BI-RADS 3, 4 after standard mammography were performed CESM. All the lesions were histologically verified.

RESULTS: 210 lesions were identified, 97 of them were malignant and 113 benign. Malignancy rates were 16.0% (8/50 BI-RADS 3), 22.7% (10/44 BI-RADS 4a), 47.5% (29/61 BI-RADS 4b) and 90.9% (50/55 BI-RADS 4c). There were 94 true-positive, 105 true-negative, 8 false-positive, and 3 false-negative (one invasive cancer, two DCIS) CESM findings, effecting a sensitivity, specificity, location sensitivity (ROC AUC) and jack-knife free-response receiver operating characteristics (JAFROC) (p < 0.001), respectively.

CONCLUSION: CESM is an accurate tool to further diagnose BI-RADS 3, 4a and 4b lesions and may be helpful to avoid unnecessary biopsies. BI-RADS 4c lesions should be biopsied irrespective of CESM findings.

SS 28 BR-02 16:10

Mammographic performance in a non-screening country: do radiologists’ interpretation differ from a screening country?

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PURPOSE: Whilst the performance of radiologists from screening countries has been increasingly investigated, the question remains on the level of performance of radiologists from non-screening countries. The objective of this study is to identify possible variations in mammographic interpretation between radiologists from screening (Australia) and non-screening (Mongolia) countries.

MATERIALS AND METHODS: Two mammographic test-sets were used: a typical screening (TS) and high difficulty (HD) test-set. Each test-set involves 60 mammographic cases with 20 cancer and 40 non-cancer images. Non-screening (NS) radiologists (n = 11) read both test-sets whilst 52 and 49 screening radiologists read the TS and HD test-sets respectively. The screening radiologists were classified into two groups: a less experienced (LE) group with up to 5 years of experience and more experienced (ME) group with more than 5 years of experience. A Kruskal-Wallis and Tukey Kramer post hoc test were used to compare reading performance among reader groups.

RESULTS: Across the three reader groups, there were significant differences in case sensitivity (p = 0.008), specificity (p = 0.006), location sensitivity (p < 0.001), receiver operating characteristics, area under curve (ROC AUC) (p < 0.001) and jack-knife free-response receiver operating characteristics (JAFROC) (p < 0.001). NS performance for all measured scores were significantly lower than those for the ME readers (p < 0.006), whilst only location sensitivity was lower (p = 0.026) for the NS compared with the LE group. No significant differences were observed for NS performance between the TS and HD test-sets.

CONCLUSION: These data provide more evidence that there is large variation in mammographic performance between radiologists from screening and non-screening countries.
Association of breast cancer and mammographic density according to age groups: single center study

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BACKGROUND: Mammographic density has been identified as risk factors for breast cancer. It varies between different age group and it can be different in various ethnic groups.

PURPOSE: To investigate the tendency of mammographic density with increasing age and association with breast cancer in Korean women.

MATERIALS AND METHODS: A total of consecutive 33,032 mammograms were included in this study from April 2003 to January 2015 at our institute (Samsung Medical Center, Republic of Korea). Our study population included 13,149 breast cancer cases and 19,883 control cases. Mammographic breast density has been classified according to the Breast Imaging-Reporting and Data System (BI-RADS) from visual assessment. Each subgroups categorized by decades of age (three groups: 10 to 30, 40 to 60, and 70 to 90) and fatty (BI-RADS 1 and 2) or dense breast (BI-RADS 3 and 4).

RESULTS: Descriptive analyses were used to examine the association between age and breast density. There was a significant inverse relationship between age and breast density (p < 0.001). Dense breast ratio of age group 40 to 60 was significantly higher in breast cancer group (breast cancer group = 72.2%, control group = 70.0%, p = 0.0001). On the other hand, there was no significant difference in the dense breast ratio between breast cancer and control groups in the age groups of 10 to 30 (breast cancer group = 91.1%, control group = 89.6%, p = 0.1748) and 70 to 90 (breast cancer group = 15.2%, control group = 18.0%, p = 0.2216).

CONCLUSION: We found an inverse relationship between patient age and mammographic density. Mammographic density partially mediated the associations between breast cancer, particularly among age group of 40 to 60.

Digital breast tomosynthesis vacuum assisted breast biopsy in the diagnosis and management of breast lesions - a single center experience

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PURPOSE: This study presents the radiological findings and pathological results of digital breast tomosynthesis (DBT) vacuum assisted breast biopsy (VABB) in the diagnosis and treatment of breast diseases.

MATERIALS AND METHODS: All women who underwent stereotactic VABB in the University Malaya Medical Centre, Kuala Lumpur from March 2017 to April 2019 were enrolled. All VABB were performed under DBT guidance and lesions were sampled using 10 Gauge vacuum biopsy device. The number of specimens obtained ranged from 5-12 core samples. The types of procedures, indications and histopathology results were documented. Comparison of the core biopsy and final surgical histopathology results were done when available and rate of histopathological upgrade were analyzed.

RESULTS: A total of 148 stereotactic guided VABB were performed, of which 137 (93%) were for suspicious microcalcifications and 11 (7%) were for architectural distortions/spiculated lesions with no sonographically detectable lesion. Histopathology results revealed 117 benign, 7 borderline and 17 malignant lesions (5 intermediate grade, 2 low grade, 7 high grade DCIS, 2 invasive carcinoma and 1 papillary DCIS). Among 17 malignant lesions, 14 lesions showed similar histopathology results after surgery. Two lesions (low grade and high grade DCIS) showed no residual lesion post-surgery due to complete removal on VABB. Another 2 lesions on VABB showed histopathological upgrade post-surgery (high grade DCIS to invasive carcinoma and borderline lesion of ADH to high grade DCIS).

CONCLUSION: The results obtained from our study confirms high efficiency of VAB in the diagnosis of mammographically indeterminate breast lesions. The diagnosis and treatment with VAB eliminates the need for open surgical procedure, decreasing the cost of breast disease management and morbidity.
Clinical utility of a new ultrasound image-processing technique for detecting breast microcalcifications
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PURPOSE: To evaluate a new commercial ultrasound image processing technique (MicroPure; Toshiba America Medical Systems, Tustin, CA, USA) on detecting microcalcifications for women with suspicious microcalcifications found on mammography and B-mode US. Also to characterize microcalcifications using mammographic and US findings according to different visibility of MicroPure imaging compared with B mode US.

MATERIALS AND METHODS: All the category 4A or higher lesions on mammography which were also found on B-mode US were included. Pathologic diagnosis for each lesion was done by US guided core-needle biopsy (n = 161), US guided vacuum assisted biopsy (VAB, n = 5), stereotactic VAB (n = 5), respectively. Under biopsy or operation, final pathology were benign (n = 29) and malignancy (n = 142). Mammography, B-mode US and MicroPure images for each 171 lesions were retrospectively reviewed according to BI-RADS. Size of microcalcifications were divided into small (punctate, fine pleomorphic and fine linear) and large (others) and extent into narrow (grouped) and wide (others). MicroPure visibility was divided into four types by comparison of the number of calcifications on two images: B > M (more on B mode than on MicroPure), B = M (similar number), B < M (more on MicroPure than on B mode) and negative (no microcalcifications on MicroPure). Pairwise or triple pairwise comparison were used to evaluate the imaging features according to MicroPure visibility.

RESULTS: Among 171 lesions, MicroPure detected microcalcifications in 91.4% (157/171). MicroPure visibility were correlated with extent and size of microcalcifications. For echogenic dots both detected on B mode US and MicroPure, additional mammography with skin marking could be skipped before US guided biopsy.

Relation of background parenchymal echotexture on breast ultrasound and background parenchymal enhancement on MRI, and variation of their relation according to hormonal status
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We studied the relationship between breast ultrasound background echotexture (BET) and magnetic resonance imaging (MRI) background parenchymal enhancement (BPE), and whether this relationship varied with hormonal status and amount of fibroglandular tissue on MRI (FGT). Two-hundred-and-eighty-three Korean women (52.1 years; range, 27-79 years) with newly diagnosed primary breast cancer who underwent preoperative breast ultrasound and MRI were retrospectively studied. BET, BPE, and FGT were classified into four categories, and age, menopausal status, menstrual cycle regularity, and menstrual cycle stage at MRI were recorded. BET and BPE relationship was assessed overall, and in menopausal, FGT, menstrual cycle regularity, and menstrual cycle stage subgroups. BET and BPE correlated in women overall, in all menopausal, FGT, and menstrual cycle subgroups, and in those in the first half (all ps < 0.001). BET reflects BPE, regardless of menopausal status, menstrual cycle regularity, and FGT, and may be a biomarker of breast cancer risk.
**SS 28 BR-07 17:00**

Potential of high-b-value diffusion weighted MRI at 3T for screening mammographically occult contralateral breast cancer in women with recently diagnosed breast cancer

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**PURPOSE:** To evaluate the performance of high b-value diffusion weighted magnetic resonance imaging (MRI) in the detection of clinically and mammographically occult contralateral breast cancers in patients with unilateral breast cancer.

**MATERIALS AND METHODS:** We identified 938 breast cancer patients who underwent preoperative breast MRI at 3T from January to June 2017. Of these, we included 324 (34.5%) patients who had no abnormalities on clinical and mammographic examinations of the contralateral breast. Two experienced breast radiologists independently reviewed DWI using b = 0 and b = 1000 s/mm², dynamic contrast-enhanced (DCE) MRI, and a combination of DWI and DCE-MRI, and recorded BI-RADS assessment category, lesion size, and mean apparent diffusion coefficient value in each case. Using histopathology or clinical 1-year follow-up as reference standards, the diagnostic yield, sensitivity, specificity, diagnostic accuracy, and the area under the receiver operating characteristic curve (AUC) of DWI, DCE-MRI, and DWI combined with DCE-MRI were compared.

**RESULTS:** A total of 6 clinically and mammographically occult contralateral cancers were identified (4 DCIS and 2 IDC; mean size, 1.8 cm; size range, 0.1-4.5 cm) in 324 patients (1.9%; mean age, 53.7; age range, 26-82 years). The average reader performance using DWI (75.0% sensitivity, 96.9% specificity, and 96.5% accuracy) had higher specificity (p < 0.01) than with DCE-MRI (100.0% sensitivity, 93.7% specificity, and 93.8% accuracy) or the combined study (91.7% sensitivity, 96.5% specificity, and 96.5% accuracy). The average AUCs were 0.916 in DWI, 0.968 in DCE-MRI, and 0.976 in DWI combined with DCE-MRI. The contralateral cancer detection yields were 13.9 per 1000 women, 18.5 per 1000 women, and 16.9 per 1000 with DWI, DCE-MRI, and DWI combined with DCE-MRI, respectively (p = 0.359).

**CONCLUSION:** High-b-value DWI at 3T showed comparable diagnostic performance to DCE-MRI for contralateral breast cancer screening with a slightly lower sensitivity but higher specificity, and the combined interpretation with DWI and DCE-MRI had higher specificity than DCE-MRI alone.

**SS 28 BR-08 17:10**

Breast cancer screening with abbreviated breast MRI: comparison of missed versus detected cancers at abbreviated breast MRI

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**PURPOSE:** To assess the screening outcomes of abbreviated breast magnetic resonance imaging (AB-MR) and to compare characteristics of breast cancers missed and detected at AB-MR.

**MATERIALS AND METHODS:** This retrospective study enrolled total 1012 patients who underwent screening AB-MR during consecutive two years between September 2015 to August 2017. AB-MR consists of T2-weighted imaging and dynamic contrast-enhanced imaging including pre-contrast and two post-contrast scans (60 and 120 s after contrast injection). For AB-MR screening, BI-RADS categories 3-5 defined positive results and BI-RADS categories 1-2 defined negative results. Cancer detection rate, sensitivity, specificity, recall rate, and positive predictive value (PPV) were assessed for each year. Reference standard was defined as a combination of pathology and 12-month follow-up. Clinicopathological and imaging characteristics of missed and detected breast cancers at AB-MR were compared.

**RESULTS:** A total of 1012 patients underwent 1935 AB-MR during consecutive two years. Over two years, cancer detection rates (1 year to 2 year: 6.9 to 8.6 per 1000), sensitivities (54.5% to 69.2%), and PPV3 (31.6% to 40.9%) increased while specificities (93.4% to 93.2%) and recall rates (7.1% to 7.5%) were similar. A total of 39 breast cancers were identified in 37 women; 27 AB-MR detected cancers and 12 AB-MR missed cancers. AB-MR missed cancers were smaller in size (mean, 1.0 cm vs. 1.9 cm; p = 0.007) and showed higher frequency of focus (41.7% vs. 7.4%, p = 0.048) and lower frequency of early washout kinetics (8.3% vs. 50.0%, p = 0.027), compared to AB-MR detected cancer. In multivariable logistic regression analysis, absence of early washout kinetics (OR, 14.4; 95% CI: 1.1, 181.1; p = 0.015) was associated with missed cancer, but other imaging variables were not significant (p > 0.05).

**CONCLUSION:** Screening outcomes of AB-MR were sustainable, with increasing cancer detection rate, sensitivity and PPV over two years. AB-MR missed cancers showed little early washout kinetics, compared to AB-MR detected cancers.
Is it necessary the breast MRI to cover the whole-level axilla for the diagnosis of axillary lymph node metastasis in patients with invasive breast cancer?  
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PURPOSE: We compared the diagnostic performance of axial breast imaging with lower axillary area (abbreviated protocol) and one with sagittal scan covering whole-level axilla (full protocol) to exclude advanced ALNM (N2-3) or high-level ALNM (at level II or III).

MATERIALS AND METHODS: A total of 435 patients were included in this study and breast MRI findings were retrospectively reviewed. Negative predictive value for cN0 to exclude advanced ALNM with MRI before the surgery and diagnostic performance for high-level ALNM with MRI at the diagnosis of breast cancer was evaluated in all patients (upfront surgery in 370 and neoadjuvant chemotherapy [NAC] in 65) and compared with using abbreviated protocol and full protocol, respectively. GEE was used for statistical analysis.

RESULTS: In NPV of cN0 for exclusion of advanced ALNM, there was no significant difference between two protocols (abbreviated protocol; 97.3% [327/336], full protocol; 98.4% [303/308], p = 0.087). The results were similar even if only NAC group was analyzed (abbreviated protocol; 83.6% [51/61], full protocol; 84.7% [50/59], p = 0.420). In the diagnostic performance for high-level ALNM, NPV and sensitivity of full protocol (NPV 97.1% [398/410], sensitivity 53.8% [14/26]) was higher than those of abbreviated protocol (NPV 95.6% [408/427] and p = 0.011, sensitivity 26.9% [7/26] and p = 0.003).

CONCLUSION: In conclusion, adding sagittal scan to evaluate axilla do not appear to be necessary for exclusion of advanced LN metastasis with or without NAC. However, it can help for assessing axillary LNs located at high level.

Ultrafast MRI using compressed sensing versus conventional MRI to distinguish benign and malignant breast lesions: a multi-reader study  
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PURPOSE: The compressed sensing (CS) technique improves spatial resolution and temporal blurring while maintaining the high temporal resolution (< 5 sec/volume) of ultrafast MRI. We aimed to compare the diagnostic performances of CS-ultrafast MRI with conventional MRI (conv-MRI) to distinguish benign and malignant breast lesions.

MATERIALS AND METHODS: A total of 99 women (mean age, 52; range, 33-84 years) with 69 tumors (62 invasive and 7 DCIS) and 30 benign lesions who underwent both CS-ultrafast and conv-MRI were identified. The CS-volume interpolated breath-hold examination (VIBE) sequence was used for the ultrafast scan (temporal resolution, 4.4 sec; voxel, 0.7 x 0.7 x 0.8 mm3, TR/TE 3.9/1.5 ms; 1 pre+16 post-contrast). The conventional VIBE sequence was used for the conventional scan (temporal resolution, 90 sec; voxel, 0.8 x 0.8 x 1.0 mm3, TR/TE 4.7/1.7 ms; 1 pre+5 post-contrast). Five radiologists blinded to the clinical information and pathologic results independently classified the likelihood of malignancy and the BI-RADS final assessment category with a 1-week interval between readings of each protocol's data set. Readers of CS-ultrafast MRI were provided with the time to enhancement at ultrafast MRI for the lesions being studied. The receiver operating characteristic curve analysis and McNemar test were performed to compare CS-ultrafast MRI and conv-MRI.

RESULTS: CS-ultrafast MRI had comparable sensitivity to conv-MRI in all readers (97.1% [67/69] vs. 94.2% [65/69]; 98.6% [68/69] vs. 100% [69/69]; 97.1% [67/69] vs. 100% [69/69]; 85.5% [59/69] vs. 100% [69/69]; 94.2% [65/69] vs. 98.6% [68/69], all ps > 0.05). One reader showed higher specificity with CS-ultrafast MRI than conv-MRI (90.0% [27/30] vs. 63.3% [19/30], p = 0.021). But, the other 4 readers showed comparable specificity for both protocols (76.7% [23/30] vs. 63.3% [19/30]; 60.0% [18/30] vs. 60.0% [18/30]; 70.0% [21/30] vs. 73.3% [22/30]; 60.0% [18/30] vs. 56.7% [17/30], p > 0.05). Az values were comparable for both protocols in all readers (0.952 vs. 0.931; 0.974 vs. 0.984; 0.978 vs. 0.990; 0.784 vs. 0.794; 0.948 vs. 0.961, all ps > 0.05).

CONCLUSION: CS-ultrafast breast MRI shows comparable diagnostic performance to conventional MRI.
Correlation of female hormone levels with quantitative BPE and ADC values in breast cancer patients: the effect of BPE and ADC values on cancer detectability
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PURPOSE: To evaluate the relationship between female hormone levels and background parenchymal enhancement (BPE) or apparent diffusion coefficient (ADC) values of normal breast parenchyma and to analyze the effect of BPE and ADC values on cancer detectability.

MATERIALS AND METHODS: From November 2016 to December 2018, 237 malignant lesions in 164 breast cancer patients who underwent preoperative MRI and female hormone testing were included in our study. For quantitative analysis of BPE, we used semi-automated in-house software with MATLAB. From each voxel of whole breast, the software calculated BPE using following equations: ((signal intensity (SI) at 1 min 30 sec after contrast injection - baseline SI)/baseline SI) × 100%. The detectability of breast cancer was scored 2 (excellent), 1 (fair), or 0 (not detectable) by two radiologists in consensus.

RESULTS: The progesterone level was significantly correlated with mean values (r = 0.226, p = 0.004), median values (r = 0.207, p = 0.008), 90th percentile values (r = 0.244, p = 0.002) and 10th percentile values (r = 0.171, p = 0.029) of quantitative BPE. There was no significant correlation between the estrogen and quantitative BPE parameters (all ps > 0.05). ADC value was not significantly correlated with both estrogen and progesterone (all ps > 0.05). Spearman rank test showed there was significant correlation between the detectability and BPE grade (r = -0.36, p < 0.001) on contrast-enhanced image or ADC values (r = -0.315, p < 0.001) on diffusion-weighted image. Of 5 lesions with score 0 on contrast-enhanced image, 3 lesions were score 2 on DWI and 1 lesion was score 1. Of 26 lesions with score 1 on contrast-enhanced image, 13 lesions were score 2 and 14 lesions were score 1 on DWI.

CONCLUSION: Quantitative BPE values were significantly correlated with progesterone level. The detectability of breast cancer depends on both BPE grade on contrast-enhanced image and ADC grade on DWI. DWI could be useful in the case of breast cancer that is not well visible on contrast-enhanced image.

Comparison of the diagnostic performance of abbreviated MRI and full diagnostic MRI with CAD system in patients with a history of breast cancer: effect of CAD kinetic features on reader performance
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PURPOSE: To compare the diagnostic performance of abbreviated MRI and full diagnostic MRI with CAD system in patients with a personal history of breast cancer and to evaluate how the kinetic features affect the performance of two radiologists.

MATERIALS AND METHODS: Between 1, 2014 and December 31, 2017, 3834 breast MR examinations in 2310 patients with a personal history of breast cancer composed our study population. MR images were retrospectively reviewed by two radiologists. First, two radiologists independently reviewed T1-weighted images scanned at 90 s after the contrast injection and T2-weighted images. After 6 months, the two readers reviewed contrast enhanced T1-weighted images with 5 consecutive delayed images using CAD. We compared the diagnostic performance of abbreviated- and full-sequence MRI.

RESULTS: Fifty-one intramammary recurrences were detected with breast MRI in 47 patients. Of fifty-one tumor recurrences, 36 (70.6%) lesions occurred at more than 3 years after initial cancer surgery and 7 (13.7%) lesions at less than 2 years after initial surgery. The sensitivity and specificity were 98% and 97.6-98.6% on the abbreviated sequence and 94.1-98% and 97.9-98.3% on full diagnostic MRI. Of 51 malignant lesions, 6 showed delayed persistent pattern, of which 3 lesions were non-mass enhancement and 3 lesions were small enhancing masses less than 1 cm.

CONCLUSION: Overall diagnostic performances of abbreviated MRI and full diagnostic MRI were similar in both readers. The CAD-generated kinetic features could affect the reader performance and the sensitivity could be improved or the specificity improved according to the readers.
Deep learning and New Technique of Breast Imaging

Chairperson(s)
Nariya Cho Seoul National University Hospital, Korea
Jeong Seon Park Hanyang University College of Medicine, Korea

SS 30 BR-01 09:50
Artificial intelligence in breast cancer detection using deep learning
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PURPOSE: Convolutional neural network is an artificial intelligence technique based on physiological principles underlying human visual cortex. Transfer learning is practice of applying previously trained machine learning algorithms to new (but related) problems. One of the mammography findings of a tumor is a mass. The study aims to evaluate the potential of a deep learning algorithm to be used for evaluation of these masses for breast cancer detection.

MATERIALS AND METHODS: Mammograms conducted at a tertiary hospital between May 17 and April 19 were studies with equivocal findings excluded resulting in 190 mammograms. Test set of 45 images was randomly selected from initial sample (27 abnormal, 18 normal) and were not used in training process. Further 37 abnormal scans were randomly excluded resulting in training set of 54 normal and 54 abnormal mammograms. Equal numbers were required in each group for optimal network training and converted to JPEG format image. Initial sample was amplified 26-fold using combination of horizontal flip, size alteration and rotation. Pre-trained Inception v3 network was then retrained using the amplified mammograms. Training data was randomly split with 80% for training, 10% for validation and 10% for final testing. Model was trained over 2000 iterations with learning rate of 0.01. The area under receiver-operator curve was calculated using web-based analysis tool.

RESULTS: The proportion of abnormal mammograms was 62%. Area under receiver-operator curve for this CNN as a diagnostic test was 0.87 demonstrating high levels of diagnostic test accuracy. Output from CNN produces a continuous score of between 0 (abnormal) and 1 (normal). Setting the output score threshold to 0.395 results in a test sensitivity of 96.3%, specificity of 66.7%, positive predictive value of 81.3% and negative predictive value of 92.3%.

CONCLUSION: This proof of concept study demonstrates that high diagnostic test accuracy can be achieved in automated analysis of mammograms. In this study CNN could never outperform radiologist since radiologist’s opinion was the ground truth. Future studies could attempt to use superior ground truth by using a consensus of many experts and histological data. This technique could be adopted across many different imaging investigations and may be very useful in improving workflow efficiency and automatically flagging abnormal scans for urgent review reducing diagnostic delay.

SS 30 BR-02 10:00
Machine learning algorithm of standard mammography phantom images for medical image quality management
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PURPOSE: To develop the machine learning based algorithm to assess the quality of standard phantom image for mammography.

MATERIALS AND METHODS: For the study, we use the standardized phantom image database of mammography in quality management center in South Korea and evaluate spatial resolution, contrast resolution and slice thickness measurement of phantom images. A total of 2800 mammography phantom images each were evaluated. Phantom images were independently labeled as two steps- 1) fibers, specks and mass to evaluate lesion according to position and characters, and 2) pass or fail. The datasets were split into training (70%), validation (15%) and test (15%). We implemented semantic segmentation using optimized convolutional neural network (CNN)-VGG model for phantom image evaluate. The performance was conducted the quantitative value using the area under curve (AUC) and the lesion detection was evaluated qualitatively by radiologists.

RESULTS: The performance showed 0.88 AUC (p < 0.003), 87.45 accuracy, 100 sensitivity and 75 specificity. The model with phantom evaluator can provide lesion location as well as more reasonable lesion detection.

CONCLUSION: Recognition of fiber, pentagon and circle with breast region evaluation model showed higher accuracy and the result of reasonable lesion detection. Machine learning with phantom imaging can be used as an adjunct to improve the accuracy for quality control.
Machine learning approaches to radiogenomics of breast cancer using low-dose perfusion CT: predicting prognostic biomarkers and molecular subtypes

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PURPOSE: To investigate the value of machine learning approaches to radiogenomics using low-dose perfusion breast computed tomography (CT) to predict prognostic biomarkers and molecular subtypes of invasive breast cancer.

MATERIALS AND METHODS: This prospective study enrolled a total of 723 cases in 241 patients with invasive breast cancer. Low-dose perfusion CT was performed in the prone position using a spectral CT device set at 80 kVp and 25 or 30 mAs (1.01-1.40 mSv). The 18 CT perfusion parameters of cancers were analyzed using five machine learning models to predict lymph node status, tumor grade, tumor size, estrogen receptor (ER) status, progesterone receptor (PR) status, HER2 status, Ki67 status, and the molecular subtypes. Accuracy and the AUC (area under the ROC curve) were calculated for the machine learning models, and the variable importance of CT parameters were evaluated in prediction of the prognostic biomarkers and the molecular subtypes.

RESULTS: The random forest is the best model for predicting prognostic biomarkers and molecular subtypes of breast cancer in terms of accuracy and the AUC. The accuracy of the random forest was higher than that of logistic regression by 11% on average: 78% vs. 65% for lymph node status, 81% vs. 66% for tumor grade, 80% vs. 71% for tumor size, 83% vs. 76% for ER status, 81% vs. 70% for PR status, 83% vs. 78% for HER2 status, 72% vs. 63% for Ki67 status, and 67% vs. 48% for the molecular subtypes. The better performance of the random forest over logistic regression was more apparent in AUC with a 0.16 margin on average: 0.84 vs. 0.66 for lymph node status, 0.90 vs. 0.72 for tumor grade, 0.86 vs. 0.74 for tumor size, 0.89 vs. 0.77 for ER status, 0.87 vs. 0.71 for PR status, 0.89 vs. 0.68 for HER2 status, 0.80 vs. 0.67 for Ki67 status, and 0.83 vs. 0.69 for the molecular subtypes. According to CT variable importance from the random forest, peak enhancement intensity (Hounsfield Units), time to peak (second), blood volume permeability (mL/100 g), perfusion of hot spot of tumor (mL/min per 100 mL), perfusion of whole tumor (mL/min per 100 mL) were the most important parameters for predicting the prognostic biomarkers and the molecular subtypes.

CONCLUSION: Machine learning approaches to radiogenomics using low-dose perfusion breast CT is a useful noninvasive tool for predicting prognostic biomarkers and molecular subtypes of invasive breast cancer.

Performance of conductivity mapping using 3T MRI in detecting breast cancers: comparison with non-contrast MRI and mammography

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PURPOSE: Breast cancers show higher conductivity than benign breast lesions. We compared the performance of conductivity map of whole breast with that of non-contrast MRI and mammography in detecting breast cancer.

MATERIALS AND METHODS: In this IRB-approved prospective study, 110 women with 112 breast cancers (103 invasive cancers [91 ductal, 12 lobular or mixed], 9 DCIS) who underwent mammography and 3T MRI including T2-weighted fast-spin echo imaging (T2WI; used for conductivity reconstruction, scan time 3 minutes) and diffusion-weighted imaging (DWI) between August 2017 and January 2018 were included. Phase-based MR electric properties tomography was used to reconstruct conductivity. For each modality, two radiologists blinded to other modalities and clinicopathological information independently evaluated the presence of breast cancer in each breast, and if present, marked a single location where cancer was most likely to be present. Another radiologist interpreted their review as one of the following categories (True positive, presence of cancer at the marking site; False positive, absence of cancer at the marking site; True negative, no marking and absence of cancer; False negative, no marking but presence of cancer). Sensitivity, specificity, PPV, and NPV were compared using generalized estimating equations. Multivariate logistic regression analysis was performed to find factors associated with cancer detectability of conductivity map.

RESULTS: Performances of conductivity map were as follows: sensitivity (25.9% in reader 1; 19.6% in reader 2), specificity (68.7%; 70.3%), PPV (41.4%; 36.7%), and NPV (60.0%; 56.3%). Sensitivity, PPV, and NPV of conductivity map were lower than those of T2WI, DWI, and mammography in both readers (p < 0.001). Specificity of conductivity map was lower...
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than that of DWI and mammography (p < 0.001), and similar with that of T2WI in both readers (p > 0.05). Both readers detected 16 cancers at its exact location of conductivity map. Invasive size alone (median size, 2 cm; ranges, 0-7.7 cm) was associated with detectability of conductivity map (odds ratio = 1.7, p = 0.045).

CONCLUSION: Current performance of conductivity map is limited and further technical development is needed to issues such as optimal reconstruction method, boundary artifact, coil-combine, etc.

**SS 30 BR-05 10:30**

Diagnostic performance of artificial intelligence (AI)-based diagnostic support software for mammography: results using a standardized test set built for external validation

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**PURPOSE:** To evaluate the diagnostic performances of an artificial intelligence (AI)-based diagnostic support software for mammography when applied to a standardized test set built for external validation.

**MATERIALS AND METHODS:** A total of 1986 mammograms were collected consecutively from four participating centers to construct a standardized test set for validation. Cancer diagnosis was based on pathological diagnosis (n = 1189, 59.9%), while benign diagnosis was based on either biopsy or benign imaging features showing stability for more than 2 years follow-up (n = 797, 40.1%). Mammography images were analyzed using Lunit INSIGHT for Mammography (Lunit Inc., South Korea), a deep learning-based software that provides per-breast malignancy scores with region-of-interests (ROIs) for suspicious malignant lesions on mammography. Diagnostic performances were evaluated using the optimized cutoff value calculated for malignancy scores.

**RESULTS:** Diagnostic performances using Lunit INSIGHT for mammography on the 1198 cases were as follows (optimal cutoff 0.068): sensitivity 90.2%, specificity 90.9%, accuracy 90.2%, and AUC 0.960, respectively. Diagnostic performances were significantly higher in mammographically-fatty breasts than dense breasts: 95.2%, 93.4%, 94.3%, 0.978 vs. 88.6%, 87.7%, 88.3%, and 0.947, respectively, and in cancer size ≥ 2 cm than in < 2 cm: 96.7%, 90.1%, 92.5%, 0.981 vs. 85.6%, 90.1%, 87.8%, 0.939, respectively.

**CONCLUSION:** The AI-based diagnostic support software for mammography showed high diagnostic performances in general, even in cases of mammographically-dense breasts and small cancers. Further validation studies using standardized test sets are anticipated to prove the clinical feasibility of various diagnostic support software in real-world practice.

**SS 30 BR-06 10:40**

Increase of cancer detection rate and reduction of false-positive recall in screening mammography using artificial intelligence – a multi-center reader study

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**PURPOSE:** To assess feasibility of artificial intelligence (AI) based diagnostic-support software whether it can be used to improve radiologists’ diagnostic performance in terms of cancer detection and false-positive recall in breast cancer screening.

**MATERIALS AND METHODS:** A total of 400 exams of screening mammograms were retrospectively collected from two institutions. For each institution, 100 cancer, 40 benign, and 60 normal exams were collected. All cancer exams were proven by biopsy. Half of the benign exams were proven by biopsy (i.e. recalled benign) while the remainder were proven by at least 2 years of follow-up imaging. 80% of the exams were randomly selected respectively from each category and each institution (e.g., 16 recalled benign for each institution). All exams were 4-view paired. A blinded multi-reader multi-case study was performed with a group of 14 radiologists for the selected 320 exams. Each radiologist reads each case without and then with aid of Lunit INSIGHT for mammography (Lunit Inc., South Korea), a deep learning-based software which shows per-breast
malignancy scores as well as region-of-interests (ROIs) for suspicious malignant lesions (Fig. 1). The difference of readers’ decision without and with AI in terms of likelihood-of-malignancy (LOM; DMIST 7-pt score) and recall-ness (recall or not) was analyzed.

**RESULTS:** Significant improvement of diagnostic performance was shown for all 14 radiologists; average LOM-based ROC AUC was 0.810 and 0.881 without and with AI, respectively (p = 0.0000047, C.I. = 95%). Based on readers’ binary decision whether each exam should be recalled or not, average cancer detection rate was increased from 75.3% to 84.8% while false-positive recalls (i.e. non-cancer recalls) were decreased from 28.0% to 25.4% where 20% of non-cancer exams were recalled benign cases.

**CONCLUSION:** This reader study showed a statistically significant improvement of diagnostic performance (0.071 increase in ROC AUC). Cancer detection rate was increased by 12.6% and false-positive recall rate was decreased by 9.6% with assistance of AI-based diagnostic-support software.

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**SS 30 BR-07 10:50**

Screening ultrasonography-detected category 4A breast masses with a decision-making support software based on deep learning as an alternative to biopsy

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**PURPOSE:** To evaluate the additional value of a decision-making support software based on deep learning (S-Detect™) in B-mode ultrasonography (US) for analyzing screening US-detected breast masses.

**MATERIALS AND METHODS:** This Institutional Review Board approved retrospective review of three institutional databases identified 299 women (median age, 44 years; range, 19-83 years) who underwent surgery between February 2016 and April 2017. Among 299 breast masses, 258 were benign and 41 were malignant (30 IDC, 7 DCIS, 2 ILC, 1 mucinous, 1 adenoid cystic carcinoma). There were 84 category 3, 174 category 4A, 20 category 4B, 14 category 4C, and 7 category 5. AUC, sensitivity, and specificity of radiologists’ BI-RADS final assessment was 0.650, 97.7% and 32.4%, respectively. In differentiating benign and malignant masses using the S-Detect™ software, quantitative scores of not-circumscribed margin, irregular shape, and not-parallel orientation were important in analyzing US-detected masses, and adding this information to B-mode US could improve diagnostic performance.

**RESULTS:** Of the 282 breast cancers, 144 (51.1%) were invasive breast cancers (< 5 cm) in 282 women (mean age, 53.5 years; range, 29-85 years) who underwent surgery between February 2016 and April 2017. Morphologic characteristics of breast cancer on B-mode ultrasonography (US) with respect to shape of mass, margin, orientation, echogenicity, and posterior features were measured using the S-Detect™ software, and quantitative scores (0-1) of each descriptor of breast cancer were recorded. The associations between quantitative scores and tumor subtype, tumor size, and lymph node status were compared using the one-way analysis of variance test or Student’s T-test.

**RESULTS:** Of the 282 breast cancers, 144 (51.1%) were classified as luminal A tumors, 77 (27.3%) as luminal B tumors, 22 (7.8%) as HER2-enriched tumors, and 39...
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(13.8%) as triple-negative tumors (ER, PR, and HER2 negative). Luminal A tumors exhibited higher irregularity scores than triple-negative tumors (mean 0.6328 vs. 0.4679, p = 0.031). Luminal B tumors exhibited higher spiculated margin scores than triple-negative tumors (mean 0.1654 vs. 0.0276, p = 0.026). In addition, tumors larger than 2 cm in size had higher scores for irregular shape (p = 0.000-0.004) than tumors smaller than 2 cm in size all tumor subtype except for HER2-enriched tumors.

CONCLUSION: Luminal A tumors and Luminal B tumors were more likely to exhibit irregular shapes and spiculated margins than triple-negative tumors. Smaller tumors tended to be rounder and more oval-shaped and to have more circumscribed margins than larger tumors in most tumors except for HER2-enriched tumors.

CLINICAL RELEVANCE: Quantitative analysis of morphologic characteristics using B-mode US with the S-DetectTM software can provide useful information regarding imaging phenotypes of breast cancer.

SS 30 BR-09 11:10
Automatic 3D segmentation of breast MR T1 images using 3D convolutional neural network
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PURPOSE: To develop and evaluate a deep learning based algorithm for the breast fibroglandular tissue (FGT) and background parenchymal enhancement (BPE) volume segmentation and classification in breast MR images.

MATERIALS AND METHODS: Total 711 women (mean age, 55.2 years; range 26-89 years) who were diagnosed with invasive breast cancer and underwent preoperative breast MR, between 2014 and 2017 were enrolled in this study. Manual segmentation was performed for the breast and FGT regions. BPE region was determined by thresholding using the subtraction image and segmented FGT mask. For classification, two radiologists independently assessed the categories of FGT and BPE of contralateral breast by consensus. Deep learning based algorithm was designed to segment and measure the volume of whole breast, FGT, and BPE and classify FGT and BPE grade. 594 patients were used for development (training and validation sets), and 117 patients for evaluation (test set). Dice similarity coefficients (DSC) and Spearman correlation analysis were used to compare the segmental results, and kappa statistics were performed for classification results.

RESULTS: The range of DSC values for breast and FGT were 0.88-0.94 (mean, 0.91 ± 0.03), 0.73-0.94 (mean, 0.83 ± 0.10), respectively. The correlation coefficient between manual segmentation and deep learning were 0.98 for breast, 0.93 for FGT, and 0.96 for BPE, respectively. Agreement in classification between deep learning based algorithm and radiologists in test set were good for FGT (k = 0.65; 95% confidence interval [CI]: 0.51, 0.78) and moderate for BPE (k = 0.46; 95% CI: 0.32, 0.59).

CONCLUSION: This deep learning based algorithm can provide reliable segmentation and classification results for FGT and BPE in breast MR images.

IMPLICATIONS FOR PATIENT CARE: FGT and BPE are known as risk factors for breast cancer and are associated with poor prognosis. Deep learning based algorithm can provide quantitative and objective information regarding imaging phenotypes of breast cancer.

Breast 16:00 - 18:00 Grand Ballroom 101
Outcome Prediction and Radiomics of Breast Cancer

Chairperson(s)
Bo Kyoung Seo Korea University Ansan Hospital, Korea
Jung Min Chang Seoul National University Hospital, Korea

SS 33 BR-01 16:00
Nomogram incorporating MRI features for predicting pathologic complete response after neoadjuvant chemotherapy for breast cancer
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PURPOSE: Previously established nomograms to predict pathologic complete response (pCR) after neoadjuvant chemotherapy (NAC) for breast cancer have been based on clinico-pathological variables alone instead of MRI features. Thus, we aimed to develop nomograms incorporating MRI features with clinico-pathological variables for predicting pCR.

MATERIALS AND METHODS: For this IRB-approved retrospective study, 359 women with stage II-III breast cancers who underwent: a) NAC, b) pre and post-NAC MRI and mammography, and c) surgery between January 2011 and September 2015 were identified (median age, 45 years; range, 22-73 years). Two
independent nomograms to predict pCR, defined as the absence of invasive cancer alone or as the absence of both invasive cancer and DCIS, were developed using logistic regression. Mammography (mass or asymmetry, calcifications, negative findings) and MRI features (lesion type, rim-enhancement, peritumoral edema, multiplicity, lesion-to-background parenchymal signal enhancement ratio (SER), lesion size, shrinkage pattern) and clinico-pathological variables (age, clinical stage, histologic grade, hormone receptor (HR) status, HER2 positivity, Ki-67, chemotherapy cycle) were input variables. Nomogram performance was evaluated with respect to discrimination and calibration and was validated using the bootstrapping method.

RESULTS: For pCR of invasive cancer alone (21%, 74 of 359), negative mammography (odds ratio [OR] = 8.7), no enhancement on MRI (OR = 3.8), SER (OR = 0.2), HR negativity (OR = 3.9), HER2 positivity (OR = 2.6), and Ki-67 (%) (OR = 1.03) were associated with pCR (all ps < 0.05). For pCR of both invasive and in situ cancer (14%, 52 of 359), no enhancement on MRI (OR = 3.8), SER (OR = 0.2), lesion size at MRI (OR = 0.6), HR negativity (OR = 3.1), and Ki-67 (%) (OR = 1.05) were associated with pCR (all ps < 0.05). Both nomograms showed good discrimination (c-index = 0.90 and 0.92, bootstrap-corrected = 0.88 and 0.90) and calibration (slope = 1, bootstrap-corrected = 0.85 and 0.87).

CONCLUSION: Our nomograms accurately predict pCR with or without DCIS and can guide treatment decisions, although external validation is needed.

SS 33 BR-02 16:10
Radiomics for prediction of breast cancer prognosis using dynamic contrast enhanced MRI (DCE-MRI)
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PURPOSE: To evaluate the value of dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) parameters as an imaging biomarker for predicting prognosis in the breast cancer, we analyzed the association with the histopathologic factors of the tumor.

MATERIALS AND METHODS: A total of 122 invasive ductal carcinomas (IDCs) in 105 women who underwent preoperative breast DCE-MRI on a 3T scanner between November 2017 and December 2018 were enrolled. Twenty-fifth, 50th, 75th percentile and coefficient of variation (CV) of each perfusion parameter (Ktrans, Kep, Ve and Vp) were calculated within each tumor. Histopathologic factors such as estrogen receptor (ER), progesterone receptor (PR), human epidermal growth factor receptor 2 (HER2), Ki-67, p53, epidermal growth factor receptor (EGFR), CK 5/6, histologic grade and lymphovascular space invasion (LVI) status were assessed. The student's t-test or Mann-Whitney U test were used for comparison of two groups and ANOVA or Kruskal-Wallis test for multiple groups.

RESULTS: Triple negative breast cancers exhibited higher Ktrans, Kep, Ve and Vp than luminal cancers (p < 0.05). ER-negative tumors showed higher Ktrans, Kep and Vp than ER-positive tumors (p < 0.05). PR-negative tumors presented higher Ve, Ve, and Vp than PR-positive tumors (p < 0.05). Tumors with higher Ki-67 showed higher Ktrans, Kep and Vp than tumors with lower Ki-67 (p
< 0.05). P53-positive tumors exhibited higher $K_{\text{trans}, \text{mean}}$, $K_{\text{trans}, \text{median}}$, $K_{\text{trans}, 75}$, $K_{\text{ep}, \text{mean}}$, $K_{\text{ep}, \text{median}}$, and $K_{\text{ep}, 75}$ than p53-negative tumors ($p < 0.05$). Higher histologic grade tumors (grade II/III) presented higher $K_{\text{trans}, \text{mean}}$, $K_{\text{trans}, \text{median}}$, $K_{\text{trans}, 75}$, $K_{\text{ep}, 25}$, $K_{\text{ep}, \text{mean}}$, $K_{\text{ep}, \text{median}}$, $K_{\text{ep}, 75}$, $V_{\text{p}, 25}$, $V_{\text{p}, \text{mean}}$, and $V_{\text{p}, \text{median}}$ ($p < 0.04$) than grade I tumor. Tumors with LVSI presented higher $K_{\text{trans}, \text{mean}}$, $K_{\text{trans}, \text{median}}$, $K_{\text{trans}, 75}$, $K_{\text{ep}, 25}$, $K_{\text{ep}, \text{mean}}$, $K_{\text{ep}, \text{median}}$, and $K_{\text{ep}, 75}$ than tumors without LVSI ($p < 0.05$). On the other hand, EGFR, CK 5/6 showed no significant correlation.

CONCLUSION: We identified breast cancer presenting higher $K_{\text{trans}}$ and $K_{\text{ep}}$ on DCE-MRI was associated with poor prognostic factors. Therefore, DCE-MRI perfusion parameters can be useful imaging biomarkers for prediction of tumor prognosis.

CLINICAL RELEVANCE/APPLICATION: DCE-MRI may be helpful to predict prognosis of breast cancer through analysis of perfusion parameters.

SS 33 BR-03 16:20
Computer-aided diagnosis-extracted kinetic heterogeneity of breast cancer at preoperative MRI imaging: relationship to distant metastasis-free survival
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PURPOSE: To investigate whether computer-aided diagnosis (CAD)-extracted kinetic features of breast cancer at preoperative magnetic resonance (MR) imaging are associated with distant metastasis-free survival in women with invasive breast cancer.

MATERIALS AND METHODS: Between November 2011 and November 2012, 283 consecutive women (mean age, 52.9 years; age range, 32-88 years) with newly diagnosed invasive breast cancer who underwent preoperative breast MR imaging were evaluated. A commercially available CAD system was used to extract the peak enhancement (highest pixel signal intensity in the first post-contrast series) and delayed enhancement profiles (washout, plateau, and persistent components of a tumor) of each breast cancer from preoperative MRI, and kinetic heterogeneity (a measure irregularities in the proportions of washout, plateau, and persistently enhancing components within a tumor) was calculated to evaluate the intratumoral heterogeneity. Cox proportional hazards models were used to reveal the associations between CAD-extracted kinetic features and distant metastasis-free survival after adjusting for clinicopathological factors.

RESULTS: In 28 (9.9%) women, distant metastasis developed at a median follow-up of 76.7 months. CAD-extracted kinetic heterogeneity was higher in women with distant metastasis than in those without distant metastasis (0.702 ± 0.197 vs. 0.434 ± 0.297, $p < 0.001$). Multivariate Cox proportional hazards analysis showed that a higher kinetic heterogeneity (hazard ratio [HR], 17.582; 95% confidence interval [CI]: 3.852; 80.263; $p = 0.009$), a higher peak enhancement (HR, 1.001; 95% CI: 1.000; 1.002; $p = 0.039$), the presence of lymphovascular invasion (HR, 3.442; 95% CI: 1.529, 7.750; $p = 0.003$), and a higher histological grade (HR, 2.285; 95% CI: 1.043, 5.009; $p = 0.039$) were associated with poorer distant metastasis-free survival.

CONCLUSION: Higher values of CAD-extracted kinetic heterogeneity and peak enhancement at preoperative breast MR imaging are associated with poorer distant metastasis-free survival of women with invasive breast cancer.

SS 33 BR-04 16:30
Pretreatment breast MRI and less-invasive axillary surgery following neoadjuvant chemotherapy: factors associated with failed sentinel node identification
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PURPOSE: To investigate the pretreatment breast MRI and clinicopathological characteristics associated with failed sentinel node (SN) identification for axillary surgery following neoadjuvant chemotherapy (NAC) in breast cancer patients.

MATERIALS AND METHODS: In this retrospective, single-institution study between January 2015 and January 2019, 241 consecutive patients (mean age, 48 years; range, 27-68 years) underwent sentinel lymph node biopsy (SLNB) for axillary surgery following NAC. Two radiologists independently reviewed imaging characteristics of axillary nodes (number, perinodal infiltration, cortical thickness) at pretreatment breast MRI. The rate of failed SN identification, clinicopathological and imaging characteristics were analyzed by multivariate logistic regression with odds ratio (OR) calculation.

RESULTS: The failed SN identification rate was 10% (25/241). Multivariate analysis showed that higher (3 or 4) clinical T stages (OR = 5.8, $p = 0.001$ for radiologist 1; OR = 4.0, $p = 0.006$ for radiologist 2), higher (10 or more) number of suspicious axillary nodes (OR = 6.6, $p = 0.007$ for radiologist 1; OR = 5.1, $p = 0.029$ for radiologist 2), and presence of perinodal infiltration (OR = 5.1, $p = 0.005$ for radiologist 1; OR = 4.2, $p = 0.021$ for radiologist 2) were independently associated with failed
CONCLUSION: The higher number of suspicious axillary nodes and the presence of perinodal infiltration at pretreatment MRI together with higher clinical T stages were independently associated with failed SN identification for axillary surgery following NAC in breast cancer patients.

**SS 33 BR-06 16:50**

Factor associated with early recurrence of breast cancer after surgery

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PURPOSE: To evaluate the factors associated with early recurrence of breast cancer within one year after surgery.

MATERIALS AND METHODS: We retrospectively reviewed the clinical data of 310 breast lesions of 293 patients who had biopsy within one year after breast cancer surgery between January 2016 to December 2018. Indications for biopsy were newly developed symptomatic lesion or suspicious lesion on follow up images. We excluded patients who underwent biopsy for extramammary lesions or lymph nodes (n = 159), who had surgery for malignant phyllodes tumor or myxofibrosarcoma or angiosarcoma (n = 19). Finally, 132 breast lesions in 126 patients were included this study. All patients had ultrasound (US) and US with mammography in 6 months and one year after surgery as a routine follow up protocol. We analyzed the results of biopsy, patient's age, the characteristics of previous cancers; histologic type, T & N stage, molecular subtype, histologic and nuclear grade, Ki-67 index, extensive intraductal component (EIC), lymphovascular invasion (LVI), history of neoadjuvant therapy (NAC), and the characteristics of biopsied lesions; location, mode of detection, imaging feature, and BI-RADS category. Multivariate logistic regression test was used for statistical analysis using SAS version 9.4 (SAS Institute, Cary, NC, USA) and p < 0.05 was considered as significant.

RESULTS: The mean age of patients was 48 years (range, 28-70 years). Forty three patients had previous mastectomy and 83 patients had breast conservation surgery and all had negative resection margin. During postoperative follow up, 96 lesions developed in ipsilateral breast or mastectomy bed and 36 lesions were in contralateral breast. Palpable abnormalities were 42 and postoperative screening detected abnormalities were 90. Mass on US was noted in 115 lesions while 17 lesions showed mammographic calcifications only. Total SN identification.

**CONCLUSION:** The sarcopenia (TAMA ≤ 83.7 cm²) measured on clinically acquired CT is a strong prognostic biomarker to predict overall survival as a patients’ factor in non-metastatic breast cancer patients.

CLINICAL RELEVANCE: The measurement of muscle mass on clinically acquired CT will help to guide management plans to optimize survival outcomes in non-metastatic invasive breast cancer patients.

**SS 33 BR-05 16:40**

Impact of sarcopenia as a prognostic biomarker of overall survival in non-metastatic invasive breast cancer

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PURPOSE: Growing evidence has indicated the importance of sarcopenia for survival in various cancers. Recently, as non-metastatic breast cancer patients live longer due to advances in diagnosis and treatment, the patients’ factors have gained emphasis including sarcopenia. Still, the evidence for prognostic value of the patients’ factors have gained emphasis including sarcopenia. Thus, the evidence for prognostic value of sarcopenia is sparse. Therefore, we aim to evaluate the prognostic value of sarcopenia. We retrospectively constructed surgical registry, non-metastatic invasive breast cancer patients.

MATERIALS AND METHODS: From the prospectively constructed surgical registry, non-metastatic invasive breast cancers treated with surgery were consecutively enrolled. Total abdominal muscle area (TAMA) was measured on clinically acquired CT images at L3 vertebrae level. The optimal cut-off value for TAMA was determined by the maximum Youden index to yield best sensitivity/specificity to predict overall survival. Univariate and multivariate Cox-hazard regression analysis was performed to evaluate prognostic value of sarcopenia.

RESULTS: A total of 394 women (mean age, 48.1 years; age range, 26-81 years) were enrolled and followed up (median follow-up 71 months, ranging 20-86 months). Of these, death occurred in 35 (8.9%) at a median of 42 months (range, 28-70 years). Forty three patients had previous mastectomy and 83 patients had breast conservation surgery.

CONCLUSION: The sarcopenia (TAMA ≤ 83.7 cm²) measured on clinically acquired CT is a strong prognostic biomarker to predict overall survival as a patients’ factor in non-metastatic breast cancer patients.
31 cases (23.5%) of biopsied lesions were diagnosed as recurrence. After Multivariate logistic regression test, presence of previous LVI, NAC and the BI-RADS category of biopsied lesion showed high likelihood of recurrence ($p < 0.001$). The recurrence was 9.3 times higher in patients with previous LVI ($p < 0.001$), and 41.3 times in patient with previous NAC ($p < 0.001$).

**CONCLUSION:** In postoperative follow up after breast cancer surgery, recurrence should be considered even within one year after surgery for the lesions with suspicious imaging features in patients with previous LVI or NAC.

**SS 33 BR-07 17:00**

What is the most predictive parameter in shear wave elastography to differentiate breast cancer and to predict tumor characteristics and immunohistochemical subtypes?

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**PURPOSE:** To identify the most predictive parameter using shear wave elastography (SWE) to differentiate breast cancer and to predict tumor characteristics and immunohistochemical subtypes.

**MATERIALS AND METHODS:** From November 2018 to February 2019, conventional breast ultrasound (US) and SWE were consecutively performed in women with BI-RADS category of 3 or above breast lesions. A total of 211 breast lesions from 190 patients were enrolled for the study, and BI-RADS categories, qualitative and quantitative SWE parameters for each lesion were prospectively obtained. Pathologic results including immunopathologic factors were evaluated. The diagnostic performance of each parameter and its correlation with immunohistochemical subtypes of breast cancer were analyzed.

**RESULTS:** Among the 211 breast lesions, there were 129 benign and 82 malignant lesions, and 142 noninvasive ductal cancer (non-IDC) and 69 invasive ductal cancer (IDC) lesions. Of all the SWE parameters, Emax showed the highest accuracy in differentiating benign from malignancy (AUC = 0.891) and non-IDC from IDC (AUC = 0.884). Also, Emax was not affected by the lesion depth and size. Poorly differentiated and PR-negative tumors showed higher Emax ($p < 0.05$). Ki-67 positive breast cancer showed more heterogeneous shear wave (high SDmean) and color distribution ($p < 0.05$). Ki-67 and CK5/6 positive breast cancers showed higher Emax/Efat ratio ($p < 0.05$).

**CONCLUSION:** Emax is a relatively accurate and stable parameter to differentiate malignancy from benign and IDC from non-IDC. In addition, the Emax/Efat ratio and heterogeneous SWE color distribution could be a predictive factor in differentiating Ki-67 positive breast cancer.

**SS 33 BR-08 17:10**

Prognostic factors associated with survival in breast cancer patients: MRI and clinico-pathologic factors associated with disease recurrence

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**PURPOSE:** To investigate prognostic factors predicting recurrence of breast cancer, focusing on imaging factors including advanced MR techniques and clinico-pathologic factors.

**MATERIALS AND METHODS:** This retrospective study was approved by our Institutional Review Board, and the requirement to obtain informed consent was waived. A total of 267 patients with breast cancer who underwent dynamic contrast-enhanced magnetic resonance imaging (MRI) before surgery from February 2014 to June 2016 was included in the study sample. Imaging parameters of MRI, including morphologic information, perfusion parameters, and texture analysis, were retrospectively reviewed by two breast expert radiologists. Patient clinical pathologic information was also reviewed. Univariable and multivariable Cox proportional hazards regression analyses were used to identify factors associated with cancer recurrence. Using Kaplan-Meier survival analysis, disease-free survival was compared between patients who experienced recurrence and those who did not.

**RESULTS:** At a median follow up of 26 months, 23 patients (8%) showed disease: five cases of ipsilateral breast or axilla recurrence, one case of contralateral breast recurrence, 15 cases of distant metastasis, and one case of both ipsilateral breast recurrence and distant metastasis. Increased ipsilateral vascularity, entropy and kurtosis from texture analysis, and multiple perfusion parameters showed significant association with disease recurrence. The Ve 25th percentile value of perfusion parameters had the highest hazard ratio of 4.37 (95% confidence interval [CI]: 1.80-11.18). Pathologic stage, especially if higher than stage II, also showed significant association with disease recurrence, independent of multiple MRI parameters. In addition, higher entropy, higher Kep 25th percentile, higher Ve 25th percentile value, and increased ipsilateral vascularity were associated with short interval time to disease recurrence by Kaplan-Meier survival analysis.
CONCLUSION: Higher pathologic stage and MRI parameters of texture parameters, perfusion parameters, and increased ipsilateral vascularity are predictors of breast cancer recurrence and may also be predictors of poor survival.

SS 33 BR-09 17:20 Multiparametric preoperative breast MRI for predicting Ki-67 proliferation index and histologic grade in early-stage luminal breast cancer
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PURPOSE: To investigate whether 3T multiparametric magnetic resonance imaging (mpMRI) can predict Ki-67 proliferation index and histologic grade in stage I-II luminal breast cancer.

MATERIALS AND METHODS: In this retrospective study, 239 consecutive women with luminal cancers underwent mpMRI and surgery. For mpMRI model, morphologic characteristics using Breast Imaging Reporting and Data system lexicon, kinetic feature using a computer-aided diagnosis (CAD), and apparent diffusion coefficient (ADC) at diffusion-weighted imaging were evaluated by two radiologists. Performance for predicting Ki-67 and histologic grade were assessed by using logistic regression analysis and the receiver operating characteristic curve (ROC) analysis.

RESULTS: Among 239 cancers, 166 (69.5%) had low Ki-67 and 73 (30.5%) had high Ki-67, and 193 (80.8%) were low grade and 46 (19.2%) were high grade. Multivariate analysis showed that intratumoral high signal intensity on T2-weighted image (odds ratio [OR] = 1.844; p = 0.046), and higher washout component (OR = 1.024; p = 0.001) were associated with higher Ki-67, and the presence of axillary adenopathy (OR = 2.719; p = 0.033), intratumoral high signal intensity (OR = 2.338; p = 0.028), larger angio-volume (OR = 1.186; p = 0.001), and higher washout component (OR = 1.033; p < 0.001) were associated with higher histologic grade. The median ADC value was 0.95 ± 0.18 × 10⁻³ mm² s⁻¹ and ROC analysis showed that it was impossible to differentiate Ki-67 and grade using ADC values (p = 0.701 and p = 0.056).

CONCLUSION: The mpMRI-derived biomarkers using tumor morphology and kinetic feature can be used for predicting proliferation index and histologic grade in early-stage luminal breast cancer.

CLINICAL RELEVANCE: Preoperative mpMRI-derived features may be used as biomarkers that help predict proliferation index and grade in patients with luminal breast cancers, thereby enabling personalized treatment.