SSE02

Breast Imaging (Quantitative Imaging and CAD)

Monday, Nov. 28 3:00PM - 4:00PM Room: E450A

BR BQ DM IN

AMA PRA Category 1 Credit ™: 1.00
ARRT Category A+ Credit: 1.00

FDA Discussions may include off-label uses.

Sungheon G. Kim, PhD, New York, NY (*Moderator*) Nothing to Disclose
Robert M. Nishikawa, PhD, Pittsburgh, PA (*Moderator*) Royalties, Hologic, Inc; Research Consultant, iCAD, Inc;

Sub-Events

SSE02-01 Concurrent CAD for Digital Breast Tomosynthesis

Monday, Nov. 28 3:00PM - 3:10PM Room: E450A

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PURPOSE

Digital Breast Tomosynthesis (DBT) is more accurate than Full-Field Digital Mammography (FFDM) alone, but prolongs reading time. A reader study evaluated the concurrent use of a Computer-Aided Detection (CAD) system to shorten reading time, while maintaining performance.

METHOD AND MATERIALS

A CAD system was developed to detect suspicious soft tissue lesions (masses, architectural distortions and asymmetries) in DBT planes. Rather than marking lesions, detected locations are extracted from the DBT planes and blended into the corresponding 2D synthetic image. Thus, lesions can be efficiently viewed in a CAD-enhanced 2D synthetic image without overlapping tissue. Twenty (20) radiologists retrospectively reviewed 240 cases in a multi-reader, multi-case (MRMC) crossover design. An enriched DBT sample included 67 malignancies in 60 patients and compared reading with CAD versus without CAD. All readers reviewed all cases with and without CAD in 2 visits separated by a memory washout period of at least 4 weeks. Radiologist performance was assessed by measuring Area Under the Receiver Operating Characteristic (ROC) Curve (AUC) for malignant lesions with CAD versus without CAD. Reading time, sensitivity, specificity and recall rate were also assessed.

RESULTS

Reading time improved 29.2% with use of CAD (95% CI: 21.1%, 36.5%; $p < 0.01$). Reader performance was non-inferior with CAD, for nonlinferiority margin delta = 0.05. Average AUC increased by 0.007 (95% CI: l0.013, 0.028; non-inferiority $p < 0.01$), from 0.839 without CAD to 0.846 with CAD. Average sensitivity increased with CAD from 0.847 without CAD to 0.870 with CAD (95% CI: -0.006, 0.053); showing a 0.032 increase in average sensitivity for soft tissue densities (95% CI: l0.002, 0.066), from 0.837 without CAD to 0.869 with CAD. Average specificity decreased from 0.525 without CAD to 0.507 with CAD (-0.018; 95% CI: -0.041, 0.005), and average recall rate for non-cancers increased from 0.476 without CAD to 0.494 with CAD (0.018; 95% CI: -0.005, 0.041).

CONCLUSION

Concurrent use of CAD results in a 29.2% faster reading time with non-inferiority of radiologist performance compared to reading without CAD.

CLINICAL RELEVANCE/APPLICATION

Concurrent use of CAD maintains high performance of DBT with a significant reduction in reading time.

SSE02-02 Dynamic Textural Analysis of Pre-treatment DCE-MRI Predicts Pathological Complete Response to Neoadjuvant Chemotherapy in Breast Cancer

Monday, Nov. 28 3:10PM - 3:20PM Room: E450A

Awards

Student Travel Stipend Award

Nathaniel Braman, Cleveland, OH (*Presenter*) Nothing to Disclose
Maryam Etesami, MD, Cleveland, OH (*Abstract Co-Author*) Nothing to Disclose
Prateek Prasanna, Cleveland, OH (*Abstract Co-Author*) Nothing to Disclose
Christina Dubchuk, Cleveland, OH (*Abstract Co-Author*) Nothing to Disclose
Donna M. Plecha, MD, Strongsville, OH (*Abstract Co-Author*) Research Grant, Hologic, Inc;
Anant Madabhushi, PhD, Piscataway, NJ (*Abstract Co-Author*) Nothing to Disclose

PURPOSE

Fewer than 30% of breast cancer patients who undergo neo-adjuvant chemotherapy (NAC) prior to surgery achieve pathological complete response (pCR). A pre-treatment dynamic contrast-enhanced MR imaging (DCE-MRI) biomarker predictive of pCR would enable more precise prognosis assessment and NAC targeting. We explore radiomic analysis of computer-extracted dynamic texture features at two DCE-MRI enhancement phases as a means of predicting breast cancer NAC response from baseline imaging.

METHOD AND MATERIALS

75 1.5T DCE-MRI scans prior to NAC were retrospectively analyzed. 22 patients had histology-confirmed pCR, while 53 had partial or non-response (NR). Computer-extracted texture features (Haralick, Co-occurrence of Local Anisotropic Gradient Orientations (CoLIAGe), and Laws) were separately extracted from initial and peak enhancement phases. The 5 most distinguishing features were selected by interaction capping and used to train a random forest classifier in a 3-fold cross-validation setting. Ability to predict pCR was assessed by area under the receiver operating characteristic curve (AUC) among all patients and within luminal (ER/PR+, 9 pCR, 41 NR) and non-luminal (triple-negative and HER2+, 13 pCR, 12 NR) patient subgroups.

RESULTS

Initial post-contrast phase texture features were effective in predicting pCR within luminal lesions (AUC = .863 ± .051), as well as identifying responders without separation by subtype (.831 ± .044). Prediction of pCR from initial phase was less reliable within the non-luminal group (AUC = .743 ± .087), yet peak contrast features better entified non-luminal responders than within luminal or all subtype groups (.831± .060 vs. .732 ± .054 and .679 ± .043). Top distinguishing features for the luminal group were homogeneity-based: standard deviation of CoLIAGe energy and sum variance, Haralick inverse difference moment. Non-luminal studies were partially identified by similar homogeneity features like CoLIAGe energy, but also by Laws energy features that detect "spottiness" and edges.

CONCLUSION

Dynamic textural analysis of DCE-MRI phases was shown to successfully predict pCR to NAC in luminal and non-luminal breast cancers.

CLINICAL RELEVANCE/APPLICATION

The ability to identify patients who will achieve pCR to NAC from baseline DCE-MRI texture features may provide a pre-treatment indicator of pathological complete response to neo-adjuvant chemotherapy, avoiding both under and over treatment of breast cancer subtypes.

SSE02-03 Could 'Deep Learning' Reduce Unnecessary Biopsies of Mammographic Microcalcifications?

Monday, Nov. 28 3:20PM - 3:30PM Room: E450A

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PURPOSE

To investigate whether a machine learning technique known as deep learning, which selects image pixel data directly (rather than human-designed features) in the extraction of image descriptors, has potential to reduce breast biopsies of benign mammographic microcalcifications without associated findings.

METHOD AND MATERIALS

The HIPAA compliant dataset contained diagnostic mammography images of biopsy-sampled BIRADS 4 and 5 lesions in 107 patients for whom the lesion was visible only as microcalcifications. There were 21 patients with breast cancer (7 invasive and 14 in situ), and 86 with benign lesions. For each image a 256x256 region of interest containing the microcalcification was selected by an expert radiologist. The region of interest was used directly as input to a deep learning method trained on a very large independent set of non-medical images. The image descriptors thus extracted were subsequently used in a nested leave-one-out-by-case (i.e., patient) model selection and classification protocol. The number of benign breast biopsies that could be avoided at zero loss in sensitivity to diagnose cancer was evaluated for the deep learning method and compared to that obtained based on a subjective probability of malignancy assigned by an expert radiologist as part of this study. Here, bootstrapping was used to assess statistical significance.

RESULTS

At 100% sensitivity, on average, the numbers of benign biopsies that could be avoided were 38 of 86 by the deep learning-based method and 11 of 86 based on the probability of malignancy assigned by the radiologist. The deep learning-based method operated at 44% specificity (95% confidence interval [34-55%]) and the study radiologist at 13% [6-20%] (p<.001). Note that clinical specificity for this dataset was zero since all lesions underwent biopsy.

CONCLUSION

There seems to be great potential for the application of deep learning methods as an aid to radiologists in the analysis of medical images.

CLINICAL RELEVANCE/APPLICATION

Reducing the number of unnecessary breast biopsies without loss in diagnostic sensitivity is an important step towards improved

Reducing the number of unnecessary breast biopsies without loss in diagnostic sensitivity is an important step towards improved breast cancer diagnosis and cost reduction.

SSE02-04 Quantitative Characteristics of Background Parencymal Enhancement in Longitudinal Breast DCE-MRIs of Healthy Women

Monday, Nov. 28 3:30PM - 3:40PM Room: E450A

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Brenda F. Kurland, PhD, Seattle, WA (*Abstract Co-Author*) Nothing to Disclose
Margarita L. Zuley, MD, Pittsburgh, PA (*Abstract Co-Author*) Research Grant, Hologic, Inc;
Wendie A. Berg, MD, PhD, Pittsburgh, PA (*Abstract Co-Author*) Nothing to Disclose
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PURPOSE

Breast DCE-MRI background parenchymal enhancement (BPE) has been reported to be associated with breast cancer risk. It became clinically important to understand key characteristics of BPE in developing it as a potential risk biomarker. In this study we investigated quantitative statistics and temporal variations of BPE in a longitudinal breast DCE-MRI dataset acquired from healthy women.

METHOD AND MATERIALS

We retrospectively identified 251 longitudinal breast DCE-MRI scans (earliest on Sep 2004 and latest on Dec 2015) from 93 women (31% have BRCA1/2 mutations) who underwent high-risk breast MRI screening at our institution (2-6 sequential scans per woman). For all the 251 scans, the average age-at-scan was 48.8±7.2 YO (range 26-67), the average between-scan time was 419±165 days (range 171-1605), and 134 (53%) were pre-menopausal with the rest post-menopausal. All 93 women remain breast cancer-free at the time of analysis. Fully automated computerized methods were applied to quantify BPE from the first post-contrast sequence at both bilateral and unilateral level. A quantitative BPE measure (BPE%) was derived as the percentage of the volume of enhanced voxels (at least 20% relative enhancement) over the fibroglandular tissue relative to the volume of fibroglandular tissue. A set of descriptive statistics were computed for BPE%, and variability of BPE% between sequential scans was measured by the intraclass correlation coefficient (ICC) in a linear mixed effects model.

RESULTS

For all 251 scans, mean BPE% was 25.1% ±13.7 (range 1.1% - 83.9%); the Pearson's correlation coefficient of BPE% between left (mean 27.4%±14.7) and right breasts (mean 24.2%±14.1) was 0.85; mean BPE% was 29.7%±15.0 (range 9.2% - 83.9%) for pre-menopausal and 20.9%±10.9 (range 1.1% - 67.0%) for post-menopausal scans (unpaired t-test $p<0.0001$). For 71 (or 48) women who had at least 2 (or 3) sequential scans, ICC of BPE% was 0.63 (or 0.46), and temporal variations of BPE% between longitudinal scans are shown in the figure.

CONCLUSION

In longitudinal DCE-MRI scans of breast cancer-free women, BPE% is highly correlated bilaterally, significantly higher among pre- than post-menopausal women, and the mean value decreases with aging.

CLINICAL RELEVANCE/APPLICATION

Quantitative characterization of BPE in longitudinal MRIs of healthy women will help determine BPE's temporal variability and reproducibility, building baseline measures for its use as a risk biomarker.

SSE02-05 Applying Data-driven Imaging Biomarker in Mammography for Breast Cancer Screening

Monday, Nov. 28 3:40PM - 3:50PM Room: E450A

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PURPOSE

To assess feasibility of data-driven imaging biomarker (DIB; an imaging biomarker that is derived from large-scale medical image data by using deep learning technology) in mammography and evaluate its potential for detection of breast cancer.

METHOD AND MATERIALS

We collected 9,757 digital mammograms from five institutions. 3,228 cancer cases were confirmed by pathology. 6,529 normal cases were defined by BIRADS final assessment category 1 without developing malignancy for 2 years. Each case includes 4 views of mammograms. 800 cases were randomly chosen as validation (n=400) and test (n=400) sets, and the remainder (2428 for cancer, 5,729 for normal) were used for training. The core algorithm of DIB-M (DIB for mammography) is deep convolutional neural network; a deep learning algorithm specialized for images. It learns discriminative features directly from training data according to the final task (cancer detection). For each case in training data, the probability of cancer inferred from DIB-M is compared with the ground-truth diagnosis result (cancer: 1, normal: 0). Then the model parameters for DIB-M are updated based on the error between the prediction and the ground-truth. Training proceeds to minimize the prediction error of the entire training set, and the final DIB-M performed the best on the validation set is used for evaluation. We performed the experiment with 3 different random-split datasets to verify performance consistency.

RESULTS

AUC was 0.813 and 0.814 for the validation and test sets, respectively. Accuracy at threshold 0.5 was 72.9% (validation) and 73.4% (test). Sensitivity (specificity) according to different thresholds for the test set is: 0.940 (0.383), 0.810 (0.635), 0.690 (0.778), 0.505 (0.903), and 0.313 (0.983) with respect to the thresholds 0.1, 0.3, 0.5, 0.7, and 0.9. ROC curves according to 3 random sets were similar (Fig.1).

CONCLUSION

This research showed the potential of DIB-M as a screening tool for breast cancer. Further studies using a large number of high-quality data including benign cases are needed to further investigate its feasibility as a screening tool.

CLINICAL RELEVANCE/APPLICATION

Unlike previous computer-aided detection (CAD) algorithms, DIB-M is purely based on data-driven features from a large-scale mammography data instead of manually designed features. With further validation, DIB-M may help radiologists to diagnose breast cancer with higher accuracy and efficiency.

SSE02-06 Computer-Aided Detection (CAD)-Generated Kinetic Features of Preoperative Breast MR Imaging: Association with Disease-Free Survival of Patients with Invasive Breast Cancer

Monday, Nov. 28 3:50PM - 4:00PM Room: E450A

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PURPOSE

To retrospectively investigate whether the kinetic features of breast cancers assessed with computer-aided detection (CAD) at preoperative magnetic resonance (MR) imaging are associated with disease-free survival in patients with invasive breast cancer.

METHOD AND MATERIALS

This is an institutional review board-approved retrospective study, with a waiver of informed consent. Between January 2012 and February 2013, 330 consecutive women (mean age, 52.9 years; age range, 32-88 years) with newly diagnosed invasive breast cancer who had undergone preoperative MR imaging and curative surgery were identified. We retrospectively reviewed all preoperative MR images using a commercially available CAD system and noted the following kinetic parameters for each lesion: peak enhancement (the highest pixel signal intensity in the first post-contrast series), angio-volume (the total volume of the enhancing lesion), and delay enhancement profiles (the proportions of washout, plateau, and persistent-enhancing component within a tumor). Cox's proportional hazards modeling was used to identify associations between CAD-generated kinetic features and disease-free survival, after controlling for clinicopathological variables.

RESULTS

A total of 31 recurrences developed at a median follow-up time of 42 months (range, 3-50 months). The mean peak enhancement was significantly higher in patients with recurrences than in those who remained disease-free (553.65 ± 686.59 vs. 249.89 ± 263.25, P=0.020). Multivariate Cox's analysis showed that a higher peak enhancement (hazard ratio [HR]=1.001, 95% confidence interval [CI]=1.000-1.002, P=0.009) and presence of lymphovascular invasion (HR=2.433, 95% CI=1.086-5.449, P=0.031) were independently, and significantly, associated with poorer disease-free survival.

CONCLUSION

A higher CAD-measured peak enhancement at preoperative breast MR imaging was independently associated with poorer disease-free survival of patients with invasive breast cancer.

CLINICAL RELEVANCE/APPLICATION

Kinetic features assessed by applying computer-aided detection (CAD) to preoperative breast MR images can be used to identify a subgroup of breast cancer patients at high risk of recurrence.