Artificial Intelligence in Breast Imaging

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Outline

• Essential AI Terminology

• Clinical Applications in Breast Imaging
  – High-Risk Breast Lesions
  – Breast Density

• Challenges
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• Challenges
AI Terminology

Artificial Intelligence

- Branch of computer science
- Intelligent human behavior
AI Terminology

- Knowledge to computers
- Generalization to new settings

AI Terminology

- Learning of features
- Improvement with more data

AI Terminology

- Artificial neural networks
- Detection of features

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• Challenges
Up to 14% of biopsies → high-risk lesions (HRLs)

High-risk lesions: ADH, LCIS, ALH, radial scar, papilloma, and flat epithelial atypia

Most benign, but surgical excision recommended because of the potential for upgrade

Resulting status quo → overtreatment
Multiple studies have investigated patient and imaging features to better stratify patients.

No definite features that allow discrimination of high-risk lesions $\rightarrow$ wide variation in treatment.

At MGH, more than 95% undergo surgery.
To develop a machine learning model that allows high-risk lesions diagnosed with biopsy that require surgical excision to be distinguished from high-risk lesions that are at low risk for upgrade to cancer at surgery and thus could be surveilled.
Materials and Methods

- Consecutive women at MGH with biopsy-proven high-risk lesions from 2006-2015

- Clinical information, mammogram reports, and pathology reports extracted from MagView
Materials and Methods

- Machine learning model: random forest classifier
  - Repeatedly selects a subset of features from the data and constructs an ensemble of decision trees that allow correct classification with the use of a constructive algorithm
  - Each decision tree is built node by node
Results

Training set
671 HRLs

Independent test set
335 HRLs

Age, biopsy pathology results, biopsy pathology report, surgical outcomes, risk factors, imaging findings

Age, biopsy pathology result (ADH), “severely atypical”

Model
Results

- 335 high-risk lesions $\rightarrow$ 38 upgrades (11.3%)
- If surgical excision of all 335 high-risk lesions:
  - 38 cancers diagnosed
  - 297 benign surgeries performed $\rightarrow$ 0 benign surgeries avoided
- If machine learning model used:
  - 37 cancers diagnosed (97.4%)
  - 206 benign surgeries performed $\rightarrow$ 91 benign surgeries avoided (30.6%)
Lack of consensus exists on appropriate management of patients with high-risk lesions.

By using the model rather than surgically excising all high-risk lesions, 97.4% (37/38) of cancers would have been diagnosed, and 30.6% (91/297) of benign surgeries could have been avoided.

Future work: incorporation of images + slides.
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Background

- Subjective estimate of fibroglanular tissue

10% 40% 40% 10%

Almost entirely fatty Scattered areas of fibroglandular density Heterogeneously dense Extremely dense
Background

- Subjective estimate of fibroglandular tissue

Almost entirely fatty

Scattered areas of fibroglandular density

Heterogeneously dense

Extremely dense
Subjective estimate of fibroglanular tissue

- Almost entirely fatty
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Decreased sensitivity
Increased risk for breast cancer
Breast Density Notification Legislation

http://www.areyoudenseadvocacy.org/dense
Background

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Almost entirely fatty

Scattered areas of fibroglandular density

Heterogeneously dense

Extremely dense
Background

Subjective estimate of fibroglandular tissue:
- Almost entirely fatty
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Purpose

- To develop a deep learning algorithm to reliably assess breast density and to validate its use in real time clinical practice
Materials and Methods

- Deep convolutional neural network: ResNet-18
  - Represent complex phenomena by iteratively composing local features layer by layer

- Trained with 41,000 mammograms and tested with 9,000 mammograms, performed 2009-11

- Reference standard: breast density as reported by radiologist at time of initial interpretation
Results

• 9,000 mammograms in the test set
  – Deep learning model 37% (vs 40%)
  – Accuracy of model 88%
  – Agreement kappa = 0.67

• Daily clinical practice
  – Acceptance of model density 97%
  – Agreement kappa = 0.91
Summary

• Important to accurately and consistently assess breast density

• Commercially available methods → mixed results

• Plan to make assessment tool open source and publicly available

• Limitation: reference standard
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Challenges

• Circumstantial
  – Cultural barrier to adoption
  – Limited investigators
  – Upfront costs

• Intrinsic
  – How best to establish the source of truth
  – Whether processing speeds will be fast enough
  – Whether criteria can be established for determining in what patient population a given program is valid

Conclusion

Artificial Intelligence

Machine Learning

Representational Learning

Deep Learning
Conclusion

Artificial Intelligence

Machine Learning

Representational Learning

Deep Learning

Prediction of High-Risk Breast Lesion Upgrade
Conclusion

Artificial Intelligence

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Representational Learning

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Prediction of High-Risk Breast Lesion Upgrade

Assessment of Breast Density
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Prediction of High-Risk Breast Lesion Upgrade

• Challenges
  – Circumstantial
  – Intrinsic

Assessment of Breast Density
Artificial Intelligence in Breast Imaging

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