



X-Ray Associates of New Mexico, P.C.

EMERGING BREAST IMAGING TECHNOLOGIES

MICHAEL N. LINVER, MD, FACR



NEW TOOLS IN BREAST IMAGING

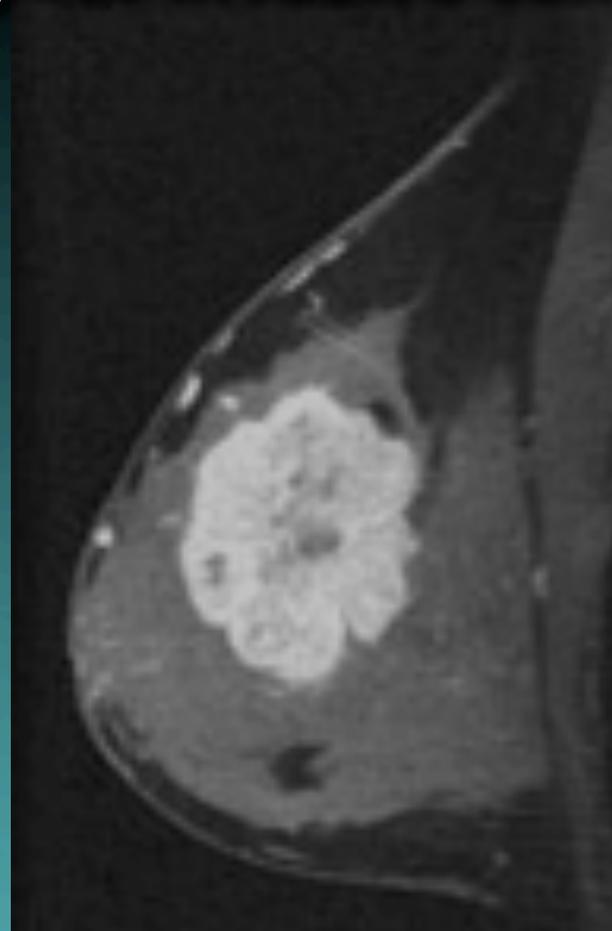
- Full Field Digital Mammography
 - Tomosynthesis, Digital Subtraction
- Optical Scanning
 - Thermography, Opto-Acoustic Imaging
- Ultrasound
 - Elastography, 3D Ultrasound
- Artificial Intelligence
 - For Mammography and Tomosynthesis



NEW TOOLS IN BREAST IMAGING

- Full Field Digital Mammography
 - Tomosynthesis, Digital Subtraction

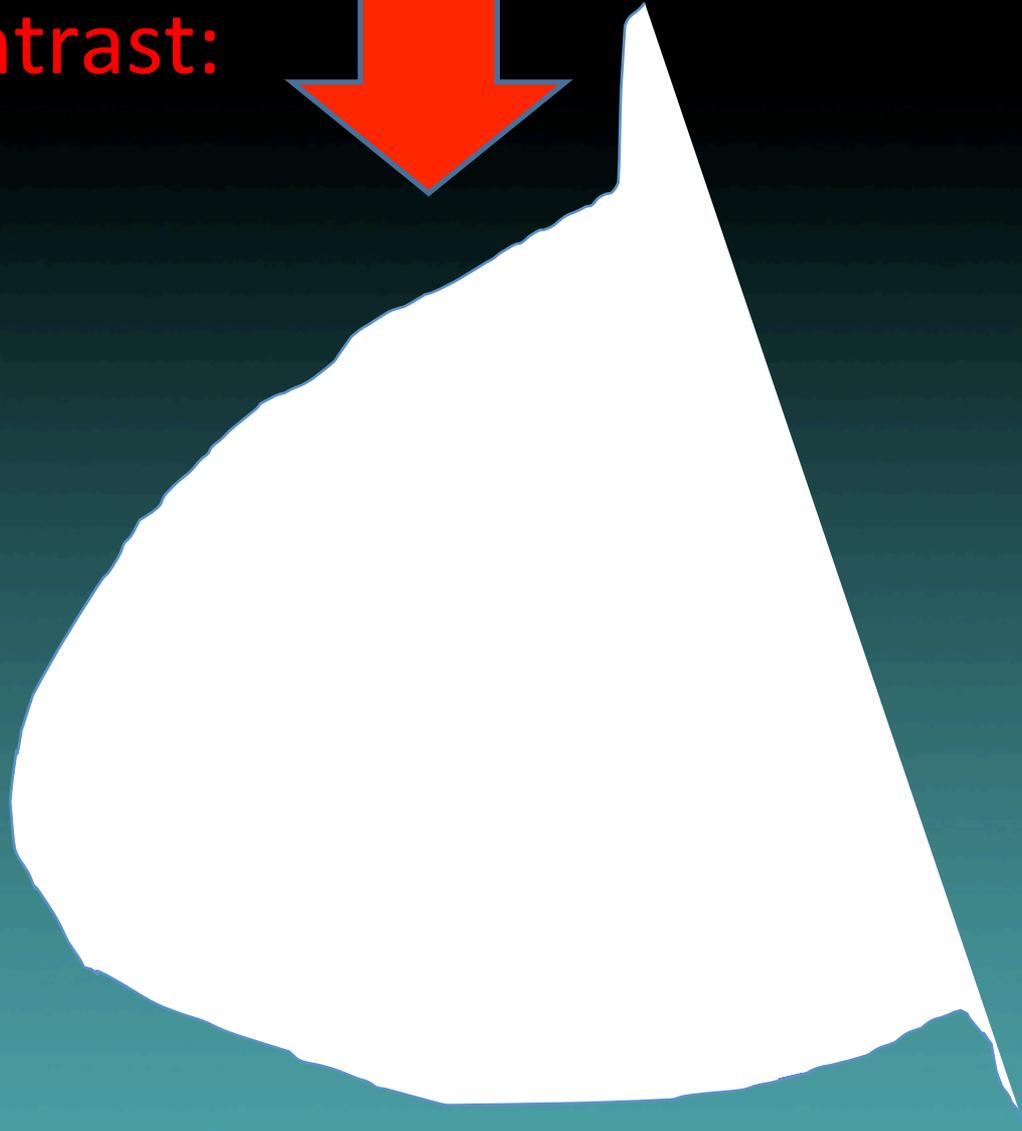
- Compared to mammography with ~85% sensitivity, **contrast-enhanced MRI** improves sensitivity for invasive cancer, approaching 100%



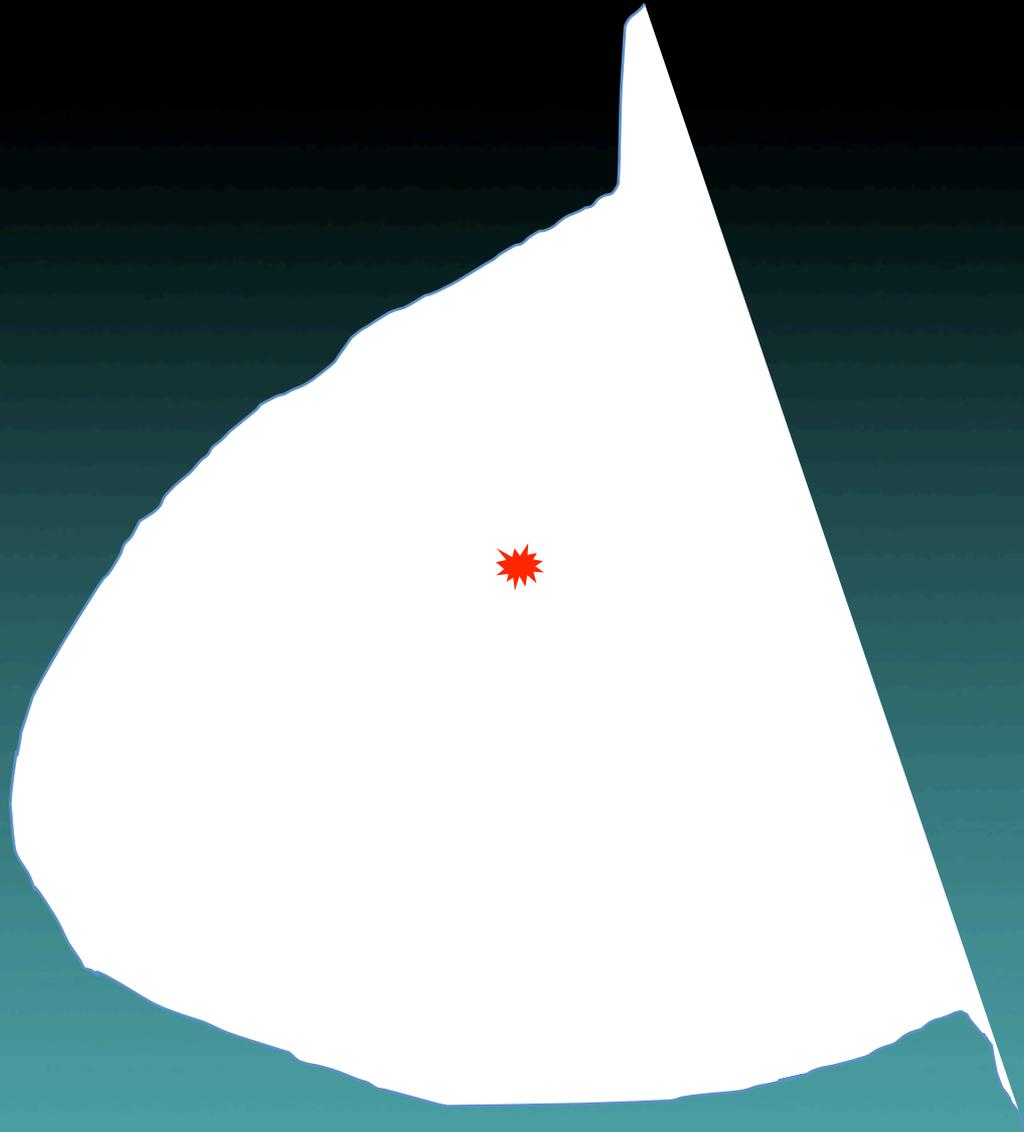
Courtesy Dr. David Dershaw



Inject contrast:



Courtesy Dr. David Dershaw



Courtesy Dr. David Dershaw

- **MRI is able to detect close to 100% of invasive breast carcinoma and 40-80% of DCIS.**
- **Mammography detects no more than 75% of breast cancers and some series suggest less than 50% of DCIS.**



- MRI is useful in breast imaging due to its ability to **map blood flow**.
- Could flow maps obtained using **digital mammographic technology** approach the usefulness of **MRI**?

YES!!!

CONTRAST ENHANCED MAMMOGRAPHY CAN!

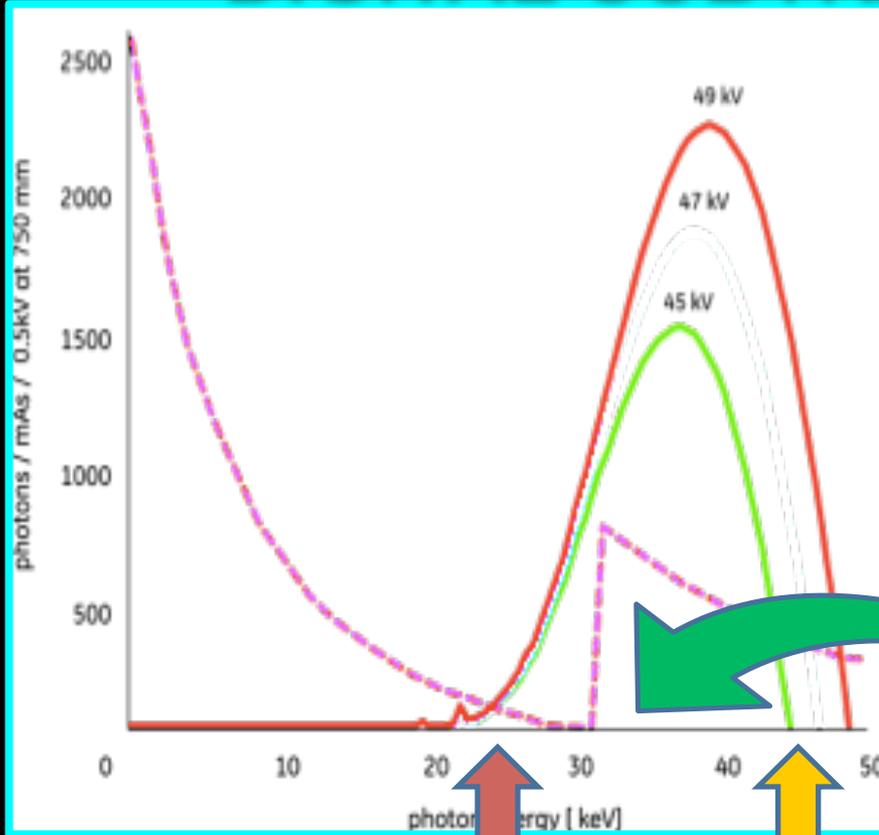




CONTRAST ENHANCED MAMMOGRAPHY (CEM) DESIGN

- **BILATERAL STUDY** with single MLO and CC image of each breast: **dual energy CEM**
- Each breast imaged at a different time point with high and low kVp.
- No dynamic information
- Normal mammogram obtained as part of study

DUAL-ENERGY CONTRAST-ENHANCED DIGITAL SUBTRACTION

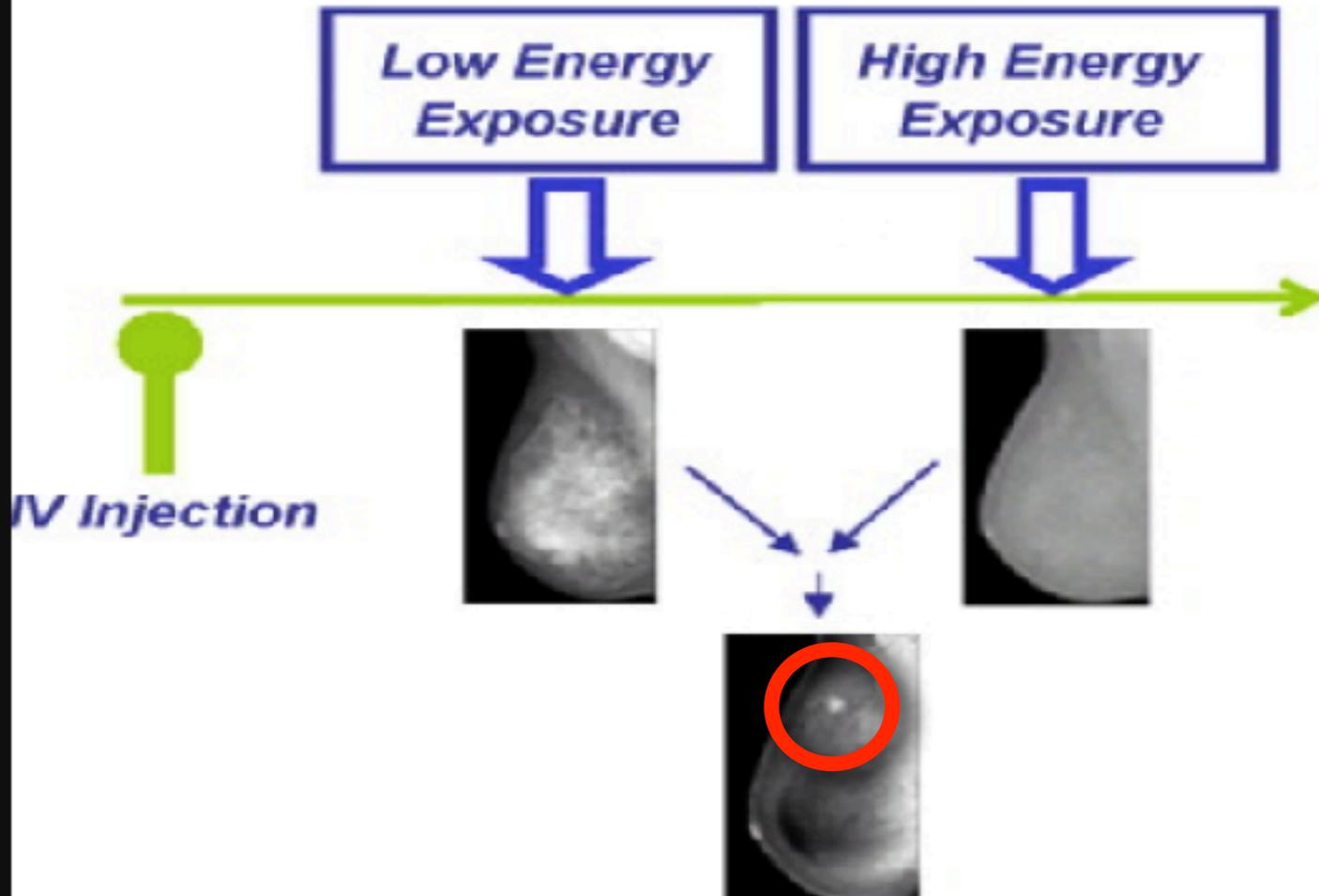


Iodine K-edge
33 Kev

kVp range for low
energy (diagnostic)
mammography

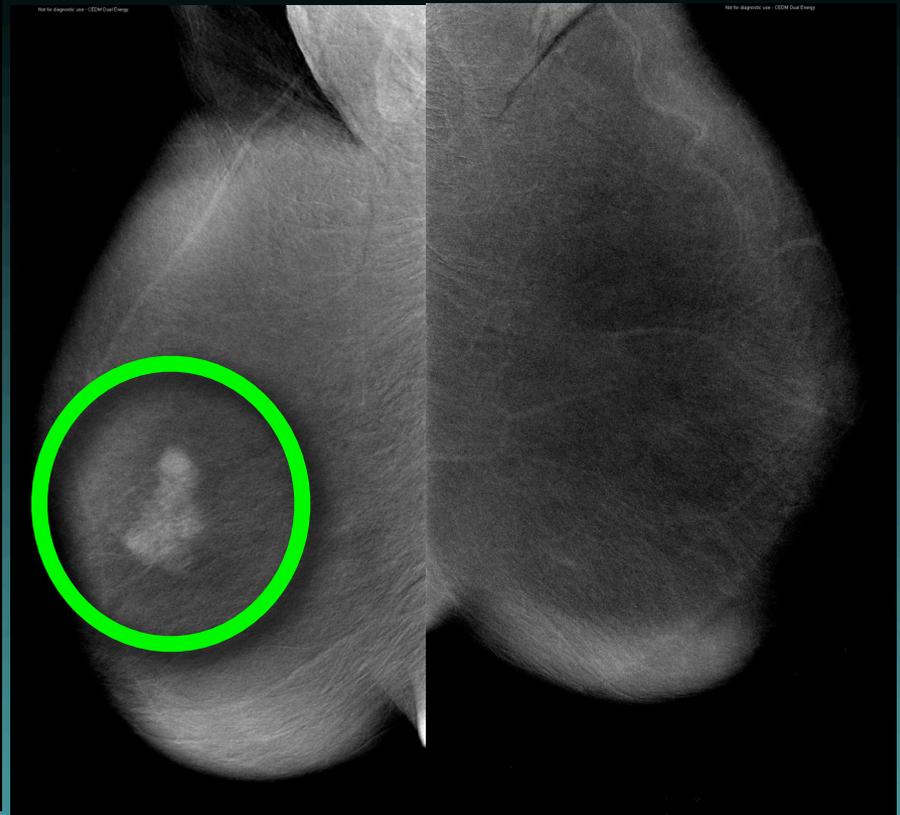
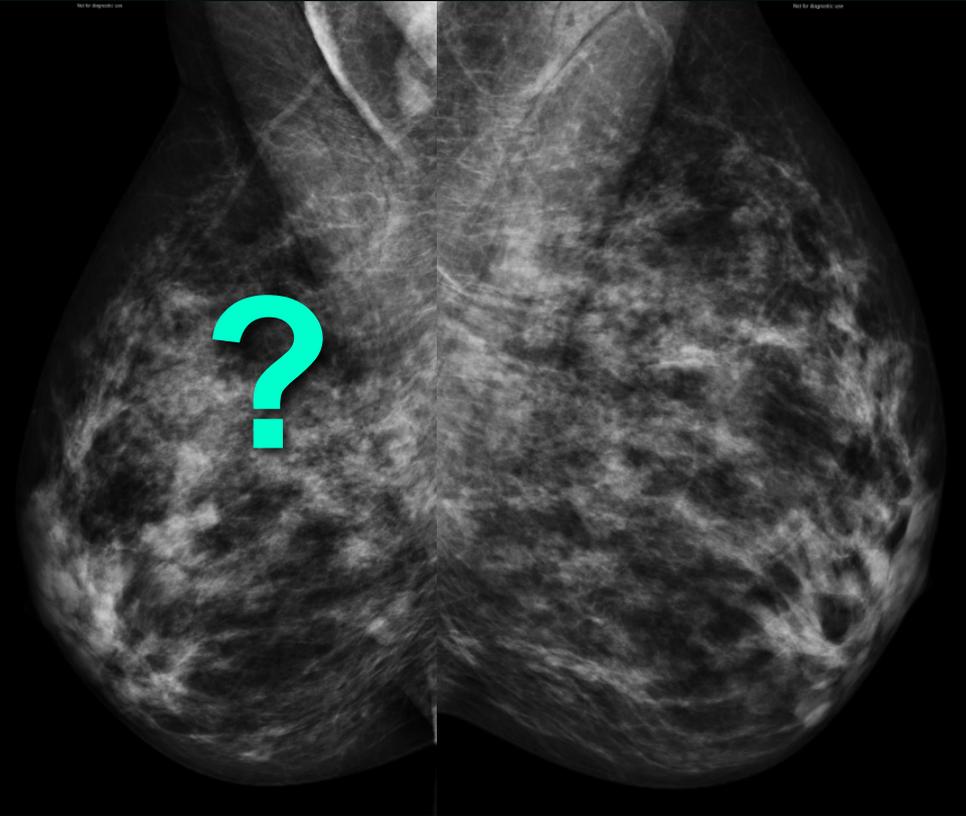
kVp range for high
energy
mammography

Dual Energy Subtraction



SCREENING MAMMOGRAM

CONTRAST ENHANCED



Courtesy Dr. David Dershaw

**How does CEM compare with
Mammography and Breast MRI in
cancer detection?**



BILATERAL CONTRAST ENHANCED MAMMOGRAPHY (CEM) VS. MRI

	Mammo	MRI	CEDM
Index CA	42/52 (81%)	50/52 (96%)	50/52 (96%)
Additional ipsilateral CA		22/25 (88%)	14/25 (56%)
Contralateral CA		0/1	0/1
TOTAL	42/78 (54%)	72/78 (92%)	64/78 (82%)
	Mammo	MRI	CEDM
False positives		13	2

52 PATIENTS WITH KNOWN CANCER

CONCLUSION:

CEM is slightly inferior to MRI in the **detection** of breast cancer and multicentricity, **but** has a much **lower false positive** rate.





CONTRAST ENHANCED MAMMOGRAPHY: POTENTIAL USES

- **Workup of indeterminate mammographic lesions**
- **Pre-op evaluation of extent of disease in pt. newly diagnosed with breast cancer**
- **Assessing response to chemotherapy**
- **Screening**

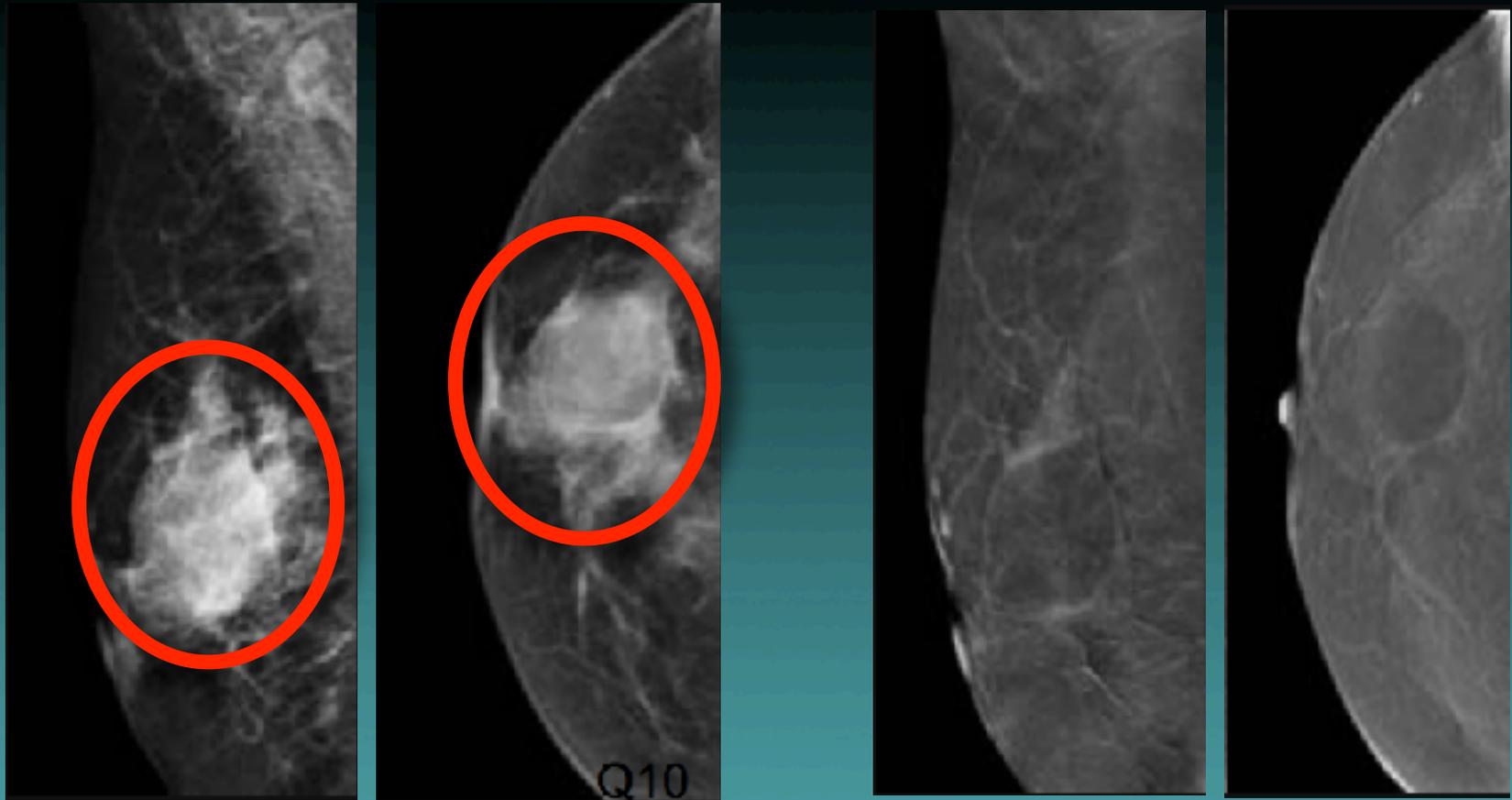


CONTRAST ENHANCED MAMMOGRAPHY: POTENTIAL USES

- **Workup of indeterminate mammographic lesions**

SCREENING MAMMOGRAM

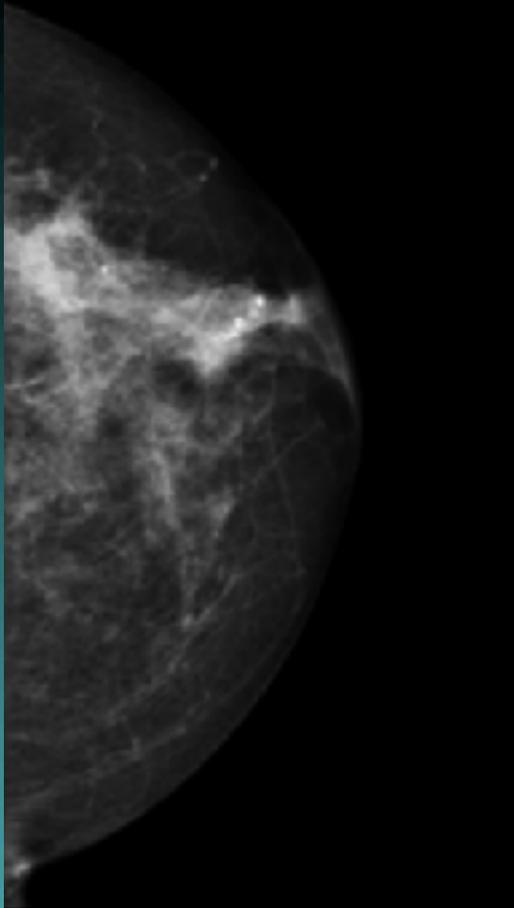
CONTRAST ENHANCED



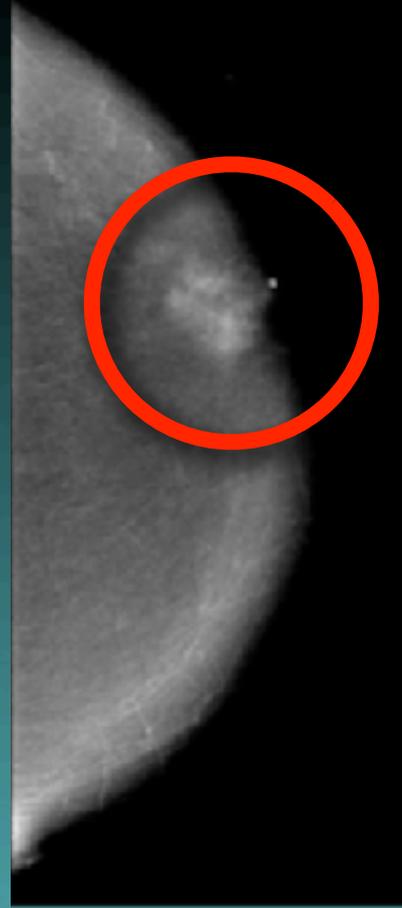
DIAGNOSIS: BENIGN (CYST)!



SCREENING MAMMOGRAM



CONTRAST ENHANCED



DIAGNOSIS: CANCER



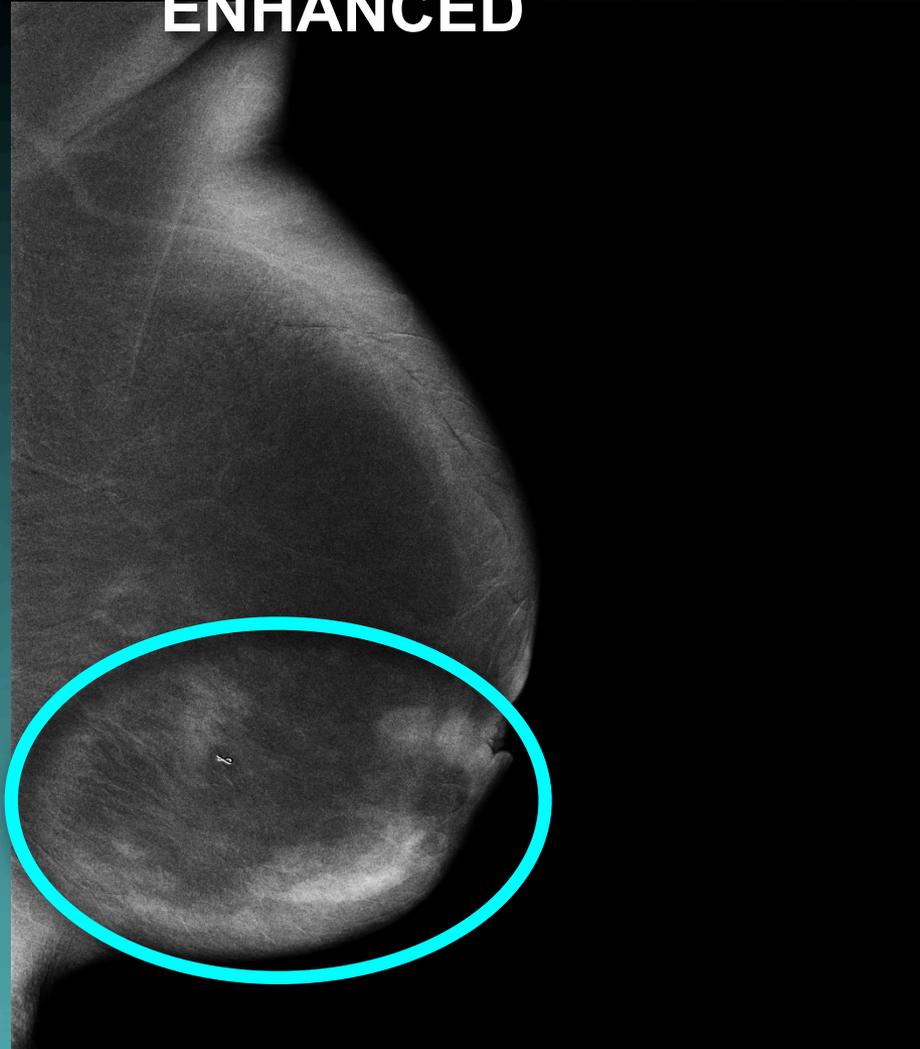


CONTRAST ENHANCED MAMMOGRAPHY: POTENTIAL USES

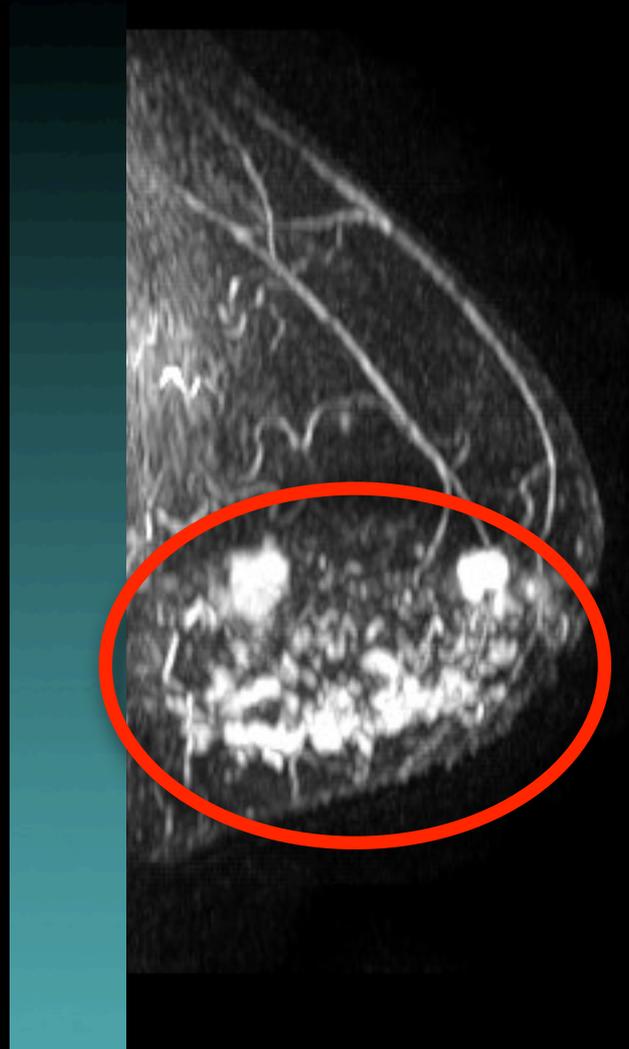
- Workup of indeterminate mammographic lesions
- **Pre-op evaluation of extent of disease in pt. newly diagnosed with breast cancer**

EXTENT OF TUMOR IN INVOLVED BREAST

CONTRAST
ENHANCED



BREAST MRI



Courtesy Dr. David Dershaw





CONTRAST ENHANCED DIGITAL MAMMOGRAPHY: POTENTIAL USES

- Workup of indeterminate mammographic lesions
- Pre-op evaluation of extent of disease in pt. newly diagnosed with breast cancer
- Assessing response to chemotherapy
- **Screening**, especially those at intermediate risk of breast cancer



BREAST MRI: OUR MOST SENSITIVE SCREENING TEST FOR BREAST CANCER DETECTION

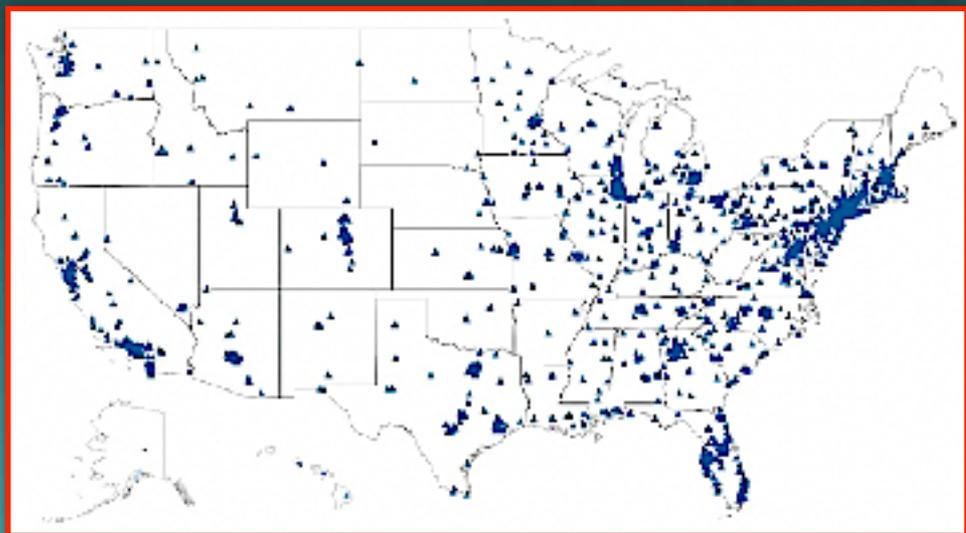
- MRI is limited to a very small subset of **HIGH RISK** women (>20% Lifetime Risk)
- Does not have the **CAPACITY** to screen women of **INTERMEDIATE RISK** (15-20% Lifetime Risk)
 - >3 million breast cancer survivors
 - >15,000 women with high risk lesions
 - 25 million women with dense breasts

MAMMO VS. MRI IN THE U.S.- 2024



MAMMO MACHINES

MRI MACHINES



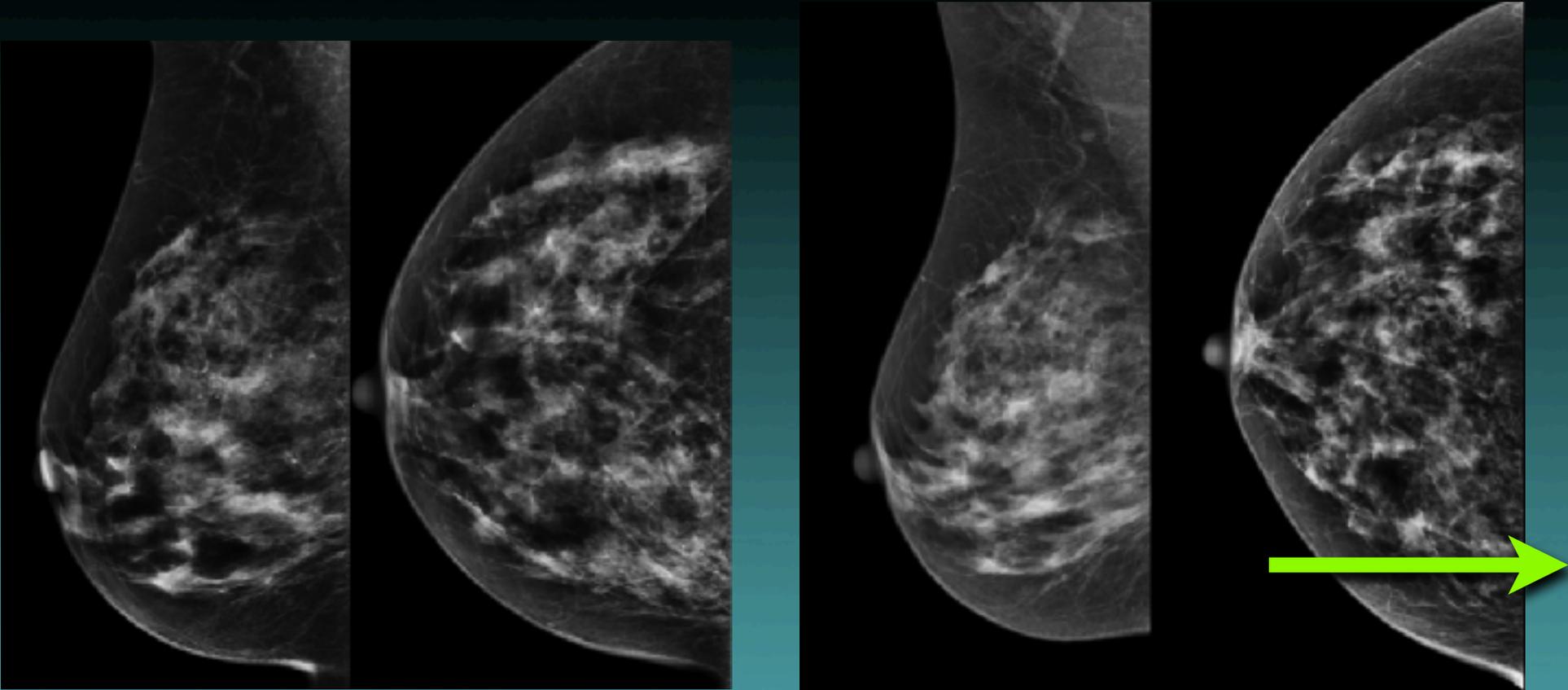
CEM CAN ACT AS A “POOR MAN’S MRI”!



50 y.o. high risk pt (previous LCIS)

SCREENING MAMMO
PREVIOUS YEAR

SCREENING MAMMO
CURRENT STUDY

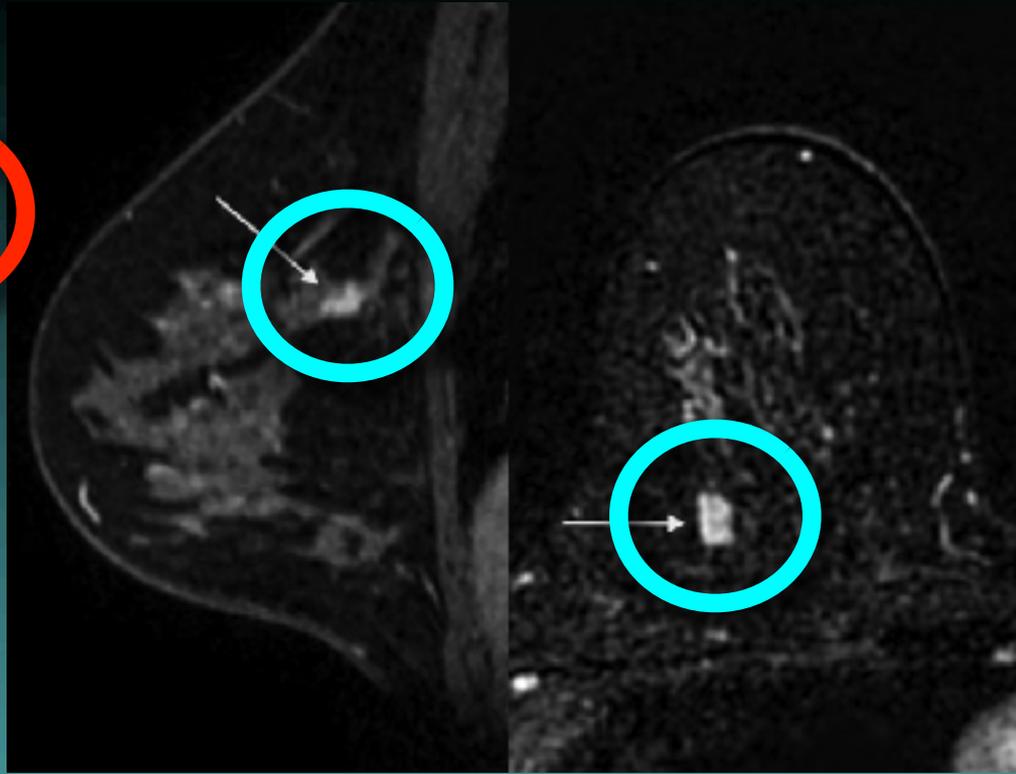


NO CHANGE, NO ABNORMALITY SEEN

50 y.o. high risk pt (previous LCIS)

SCREENING CEM

SCREENING MRI



INVASIVE LOBULAR CARCINOMA





CONTRAST ENHANCED MAMMOGRAPHY: POTENTIAL ADVANTAGES

- **Done at same time as routine mammography**
- **Low cost**
- **Improved sensitivity and specificity**
- **Much greater accessibility compared to MRI**
 - ➔ **Can be added directly to current mammo machines!**



CEM: WHAT ARE THE LIMITATIONS?

- Radiation dose is 20-25% greater than a routine mammogram, the equivalent of one extra image.
- Requires injection of iodinated contrast
- Some false positives
- Biopsy of CEM-only finding:
Biopsy system now available!!



CEDM: WHAT ARE THE LIMITATIONS?

- Radiation dose is 20-25% greater than a routine mammogram, the equivalent of one extra image.
- **Requires injection of iodinated contrast.**
- False positives
- Biopsy of CEDM-only finding

IODINATED CONTRAST REACTIONS VS. GADOLINIUM REACTIONS

Factors	MRI ¹ (Gd)	X-ray ² (I)
Standard of care	✓	
Risk of adverse reaction	✓	✓
Risk of Severe Reaction	15/100,000	160/100,000
Risk of Death	1/100,000	1/100,000

1. Hunt et al. Frequency and Severity of Adverse Effects of Iodinated and Gadolinium Contrast Materials: Retrospective Review of 456,930 Doses
2. Caro et al. The risks of death and of severe nonfatal reactions with high- vs low-osmolality contrast media: a meta-analysis. AJR April 1991, Volume 156, Number 4

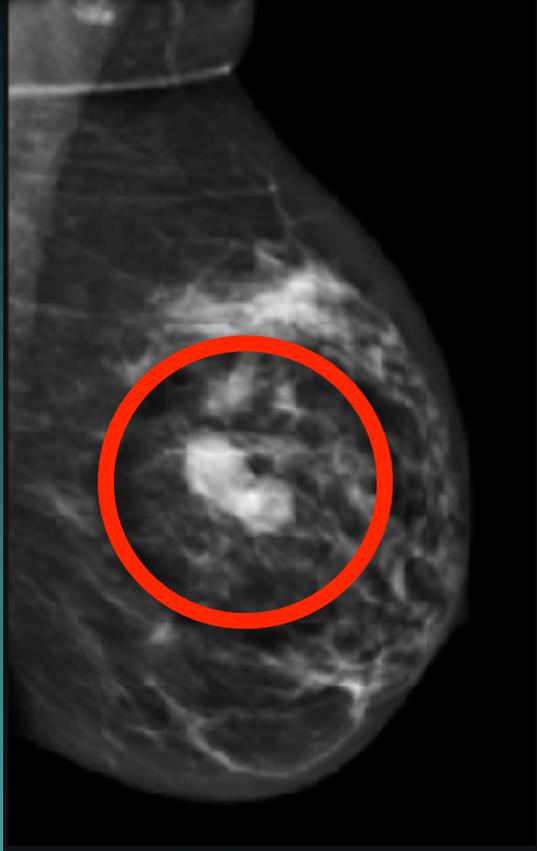


CEDM: WHAT ARE THE LIMITATIONS?

- Radiation dose is 20-25% greater than a routine mammogram, the equivalent of one extra image.
- Iodinated contrast administration.
- **Some false positives, but less than MRI**

FALSE POSITIVE STUDY

**SCREENING
MAMMOGRAM**



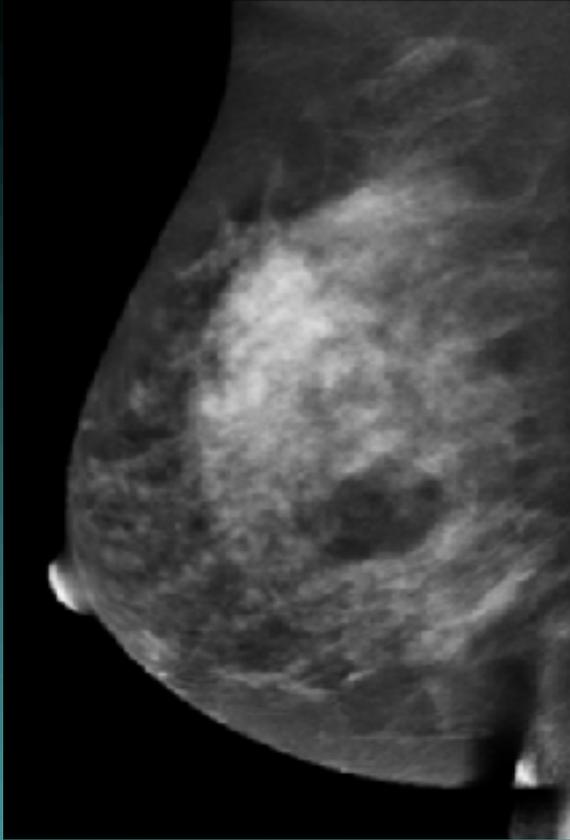
**CONTRAST
ENHANCED**



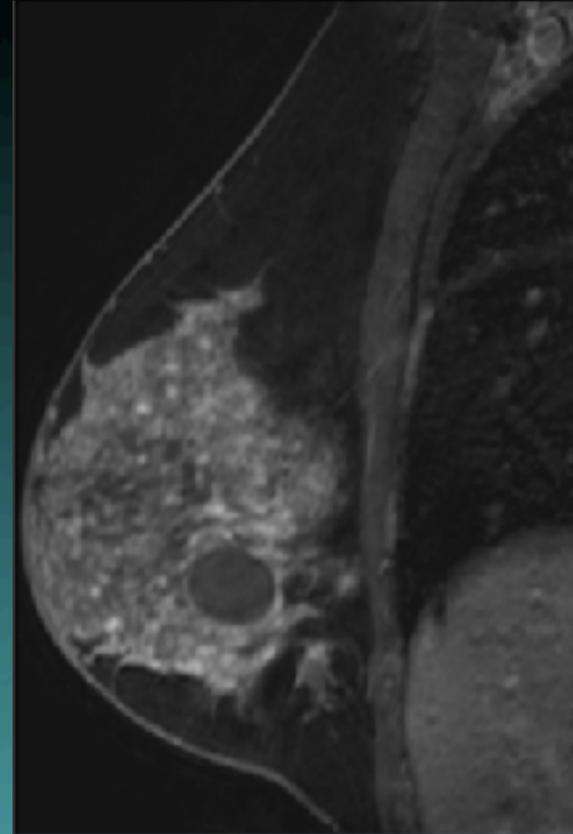
BIOPSY: FIBROADENOMA



CEM MAMMOGRAM



BREAST MRI



**BACKGROUND PARENCHYMAL
ENHANCEMENT (BPE)**

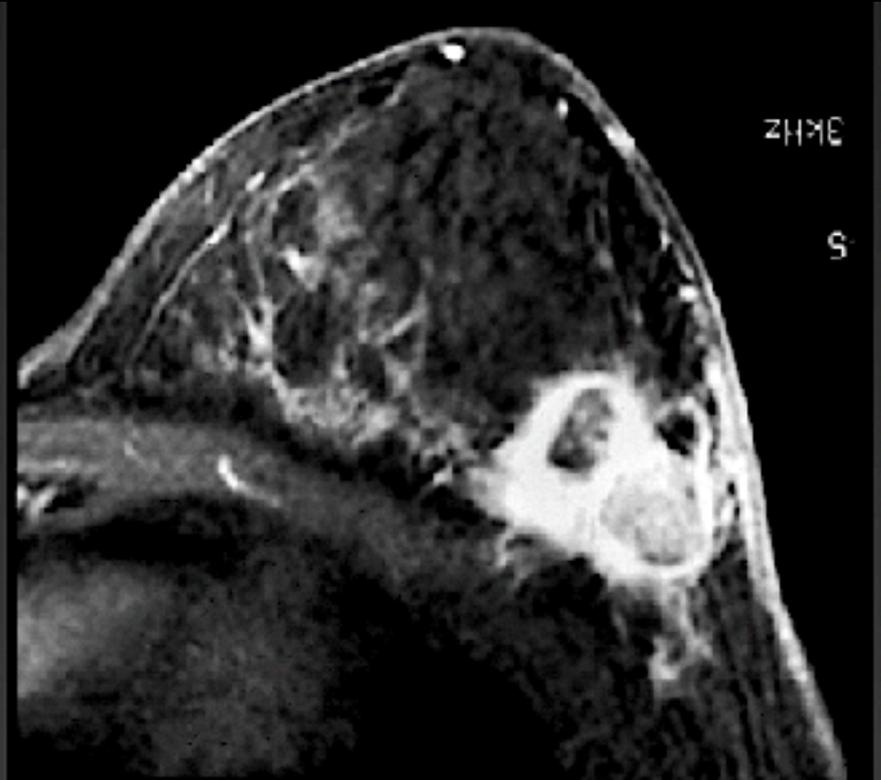
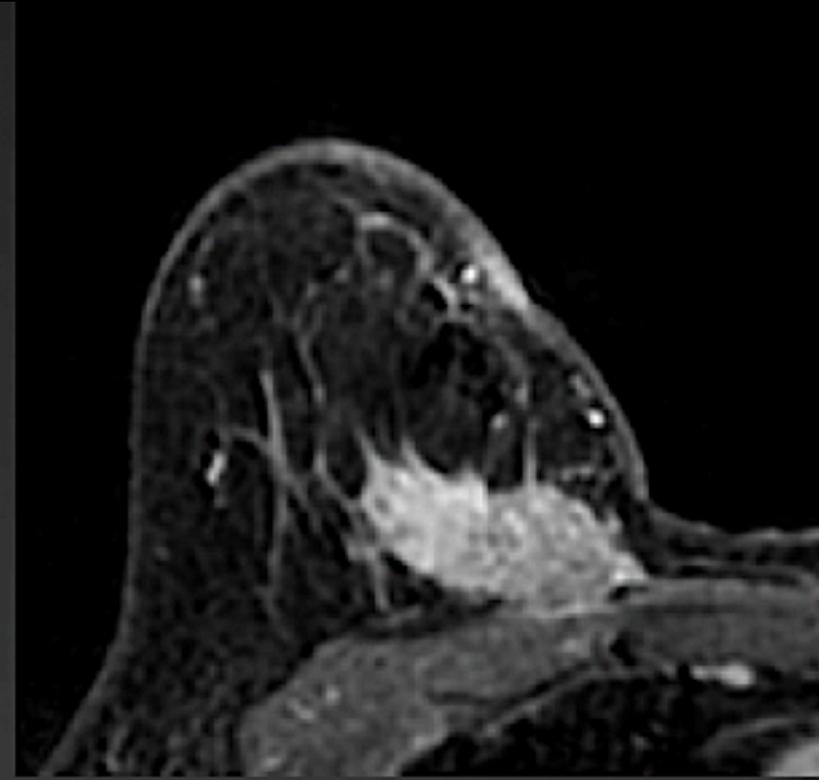




CEM: WHAT ARE THE LIMITATIONS?

- Radiation dose is 20-25% greater than a routine mammogram, the equivalent of one extra image.
- Requires injection of iodinated contrast.
- Some false positives
- **Does not image the posterior breast or the chest wall**

MR IS BETTER THAN CEM IN IMAGING SOME AREAS:



Cancer on the edge of view

Chest wall or Pectoralis Muscle involvement

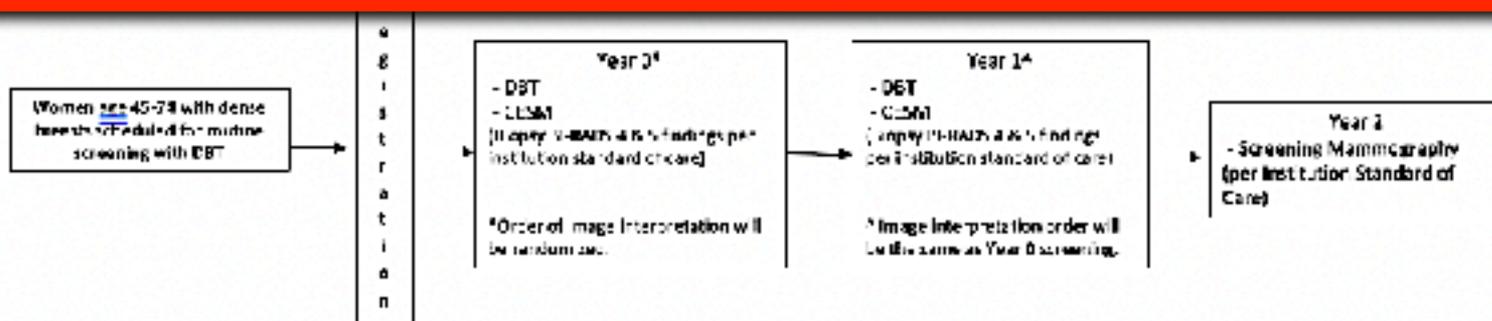


CEM SCREENING TRIAL NOW UNDERWAY:

CMIST

Contrast Mammography Imaging Screening Trial

Comparison of Breast Cancer Screening with Dual-Energy Contrast-Enhanced Spectral Mammography to Digital Breast Tomosynthesis in Women with Dense Breasts



Evaluate Potential Improvements in Breast Cancer Screening for Women with Dense Breasts

The Contrast Enhanced Mammography Imaging Screening Trial (CMIST) is a planned clinical evaluation designed to determine if using Contrast Enhanced Mammography in breast cancer screening can improve breast cancer detection for women with dense breasts.

Investigator Sponsored Research Investigator:

Christopher Comstock, MD FACR

Managed and Sponsored By:

American College of Radiology

Supported By:

GE Healthcare and the Breast Cancer Research Foundation



RESULTS SHOULD BE AVAILABLE SOON!





NEW TOOLS IN BREAST IMAGING

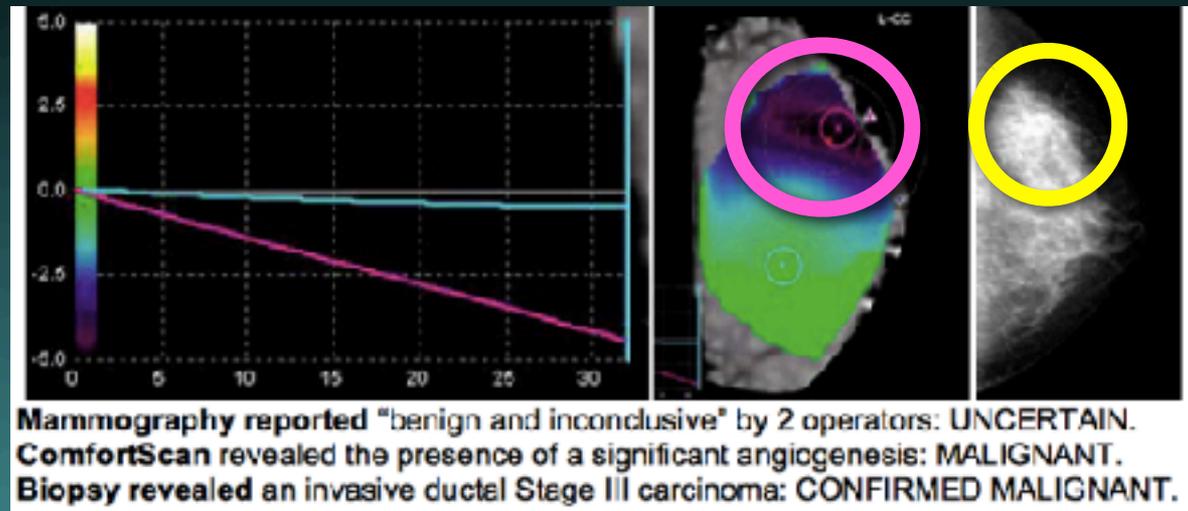
- Full Field Digital Mammography
 - Tomosynthesis, Digital Subtraction
- Optical Scanning



OPTICAL SCANNING

- **Opto-Acoustics**
 - **A promising Fusion technology**
 - **Grew out of Dynamic Optical Breast Imaging (DOBI)**

DOBI (Dynamic Optical Breast Imaging):
Diodes emit red light with wavelength of 640 nm
through the breast, showing areas of increased
blood flow, and light is recorded on CCD camera



No definitive studies showing its benefit



Opto-Acoustics

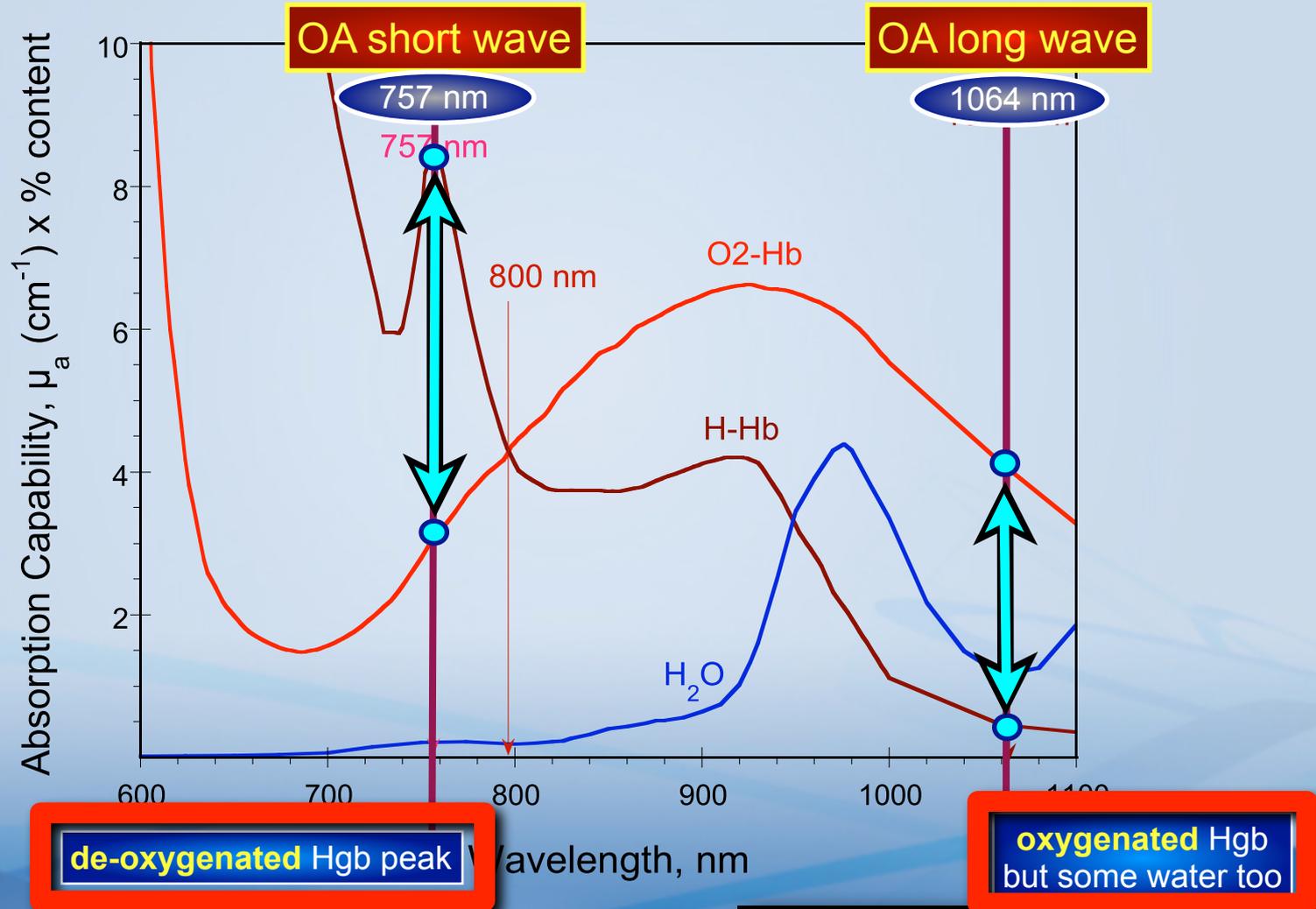
The Basic Assumptions

➤ Opto-acoustics - functional imaging

- Cancers are metabolically more active, and therefore, de-oxygenate blood more than either:
 - ▶ normal tissues or
 - ▶ benign lesions
- Opto-acoustics can demonstrate relatively greater de-oxygenation that occurs within malignant lesions

Optical Absorption within Breast Tissues

- at two laser wavelengths

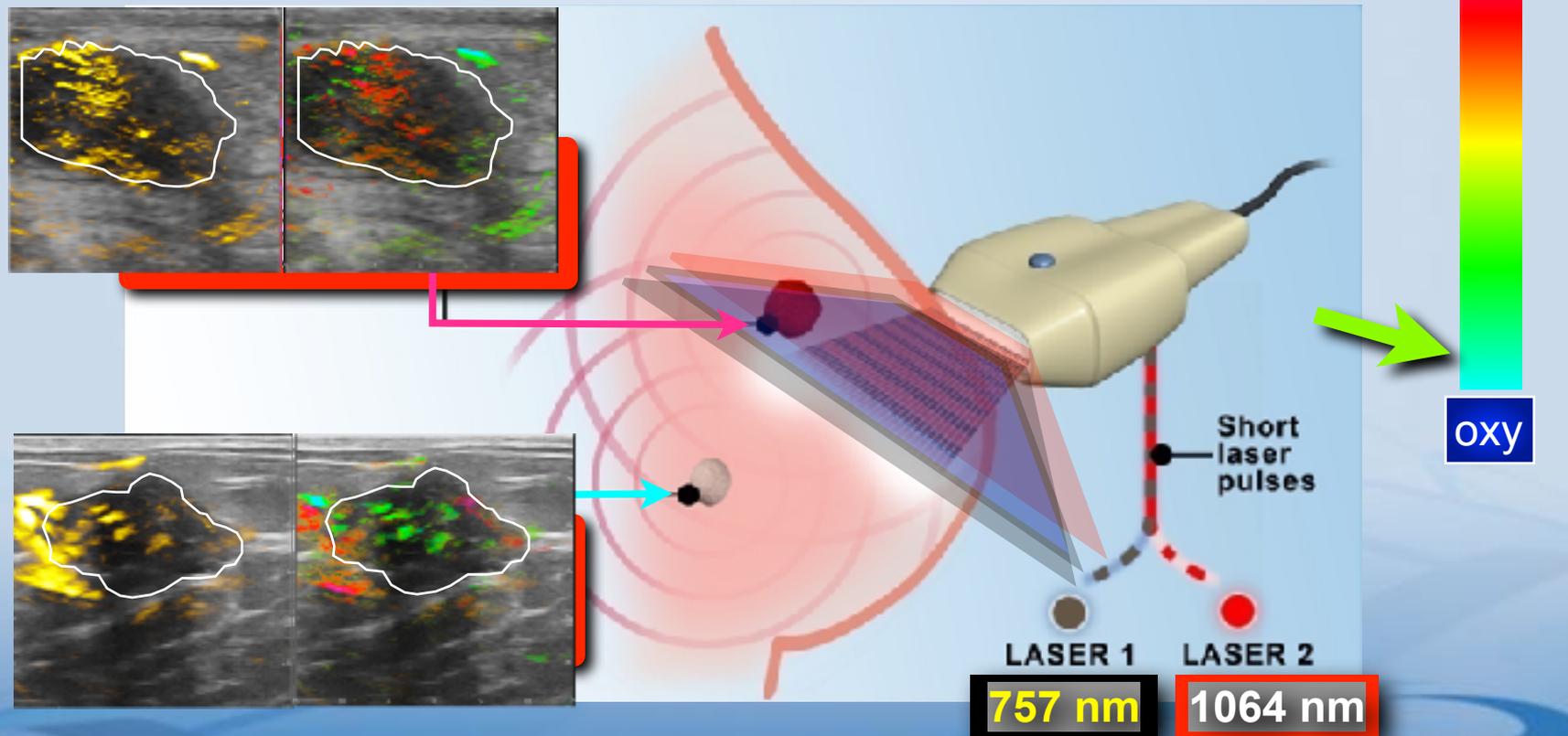


"IMAGINATION IS JUST THE BEGINNING."

Opto-Acoustic (OA) and Ultrasound Images

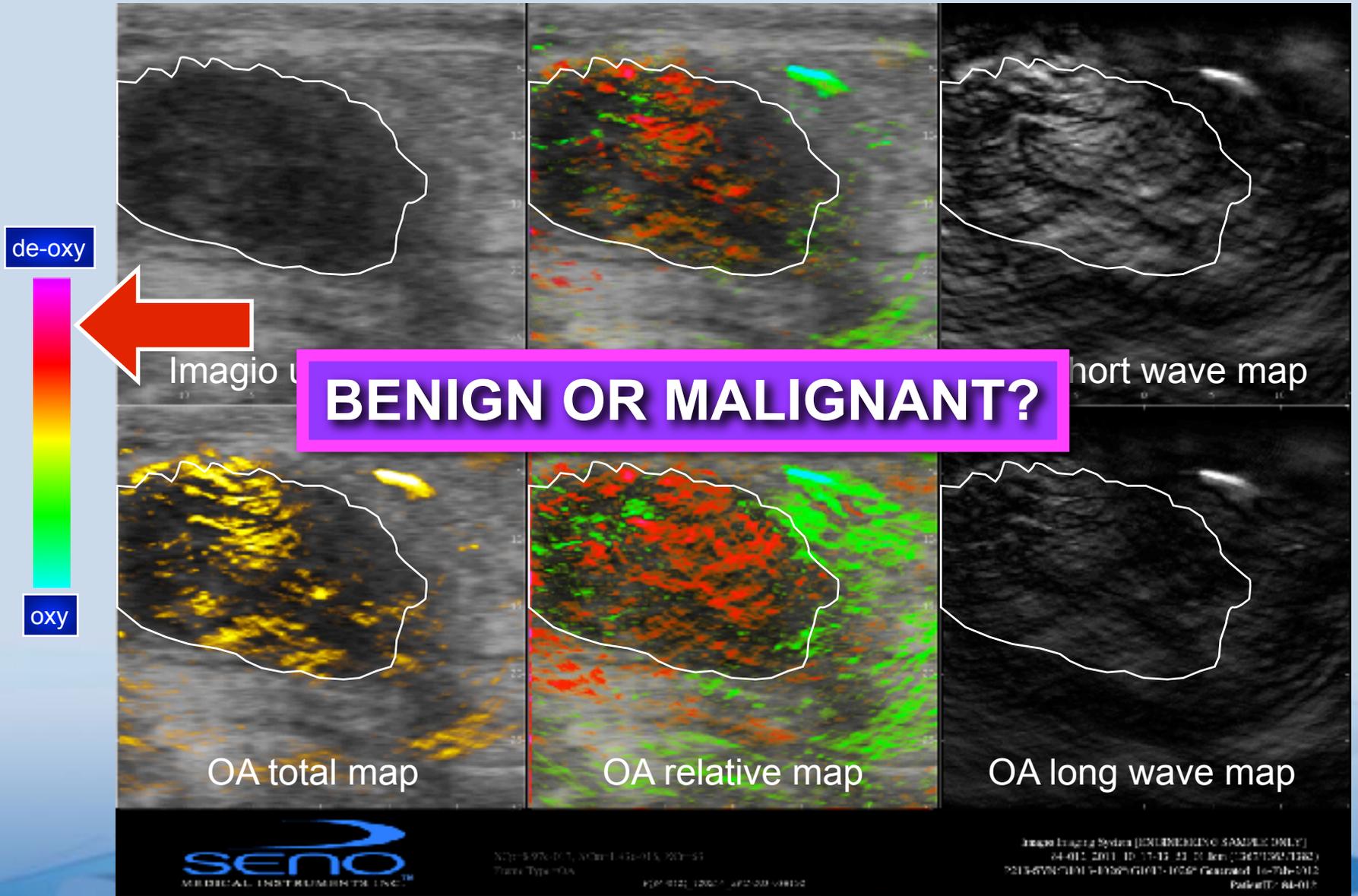
- co-registered
- temporally interleaved

- real time
- color coded



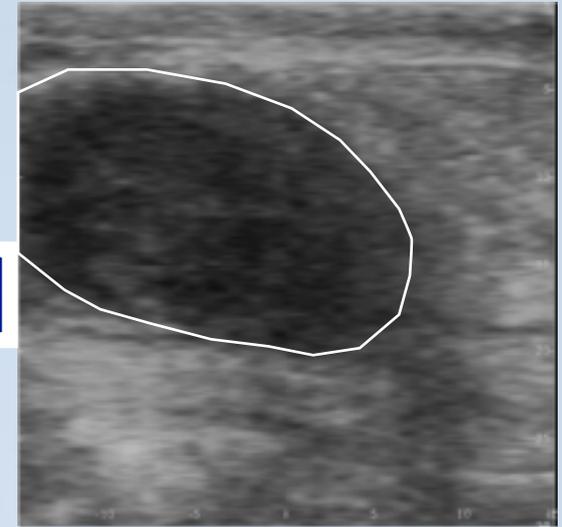
"IMAGINATION IS JUST THE BEGINNING."

Internal Findings - IDC, gr 3 - OA ff #1

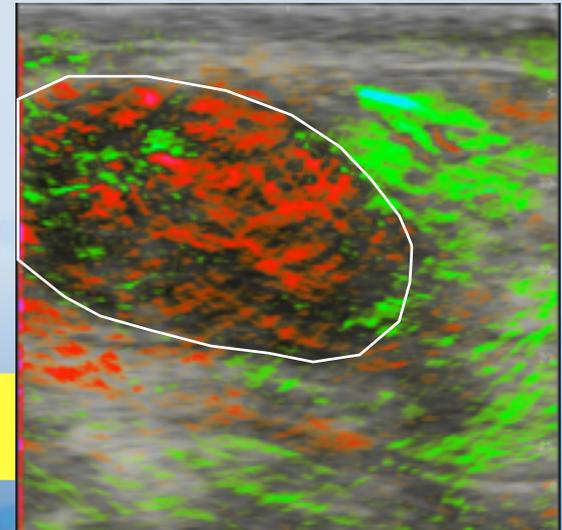


"IMAGINATION IS JUST THE BEGINNING."

US appearance overlaps that of benign lesions



but the OA appearance does not look benign



"IMAGINATION IS JUST THE BEGINNING."

Thus we need to look at both:

...internal (primarily function) OA findings...

...and...

...external (primarily morphologic) OA findings...

...in order to optimize OA sensitivity

A GREAT NEW TOOL FOR BREAST CANCER DETECTION!

"IMAGINATION IS JUST THE BEGINNING."



NEW TOOLS IN BREAST IMAGING

- Full Field Digital Mammography
 - Tomosynthesis, Digital Subtraction
- Optical Scanning
 - Thermography, Opto-Acoustic Imaging
- **Ultrasound**
 - **Elastography, 3D Ultrasound**



BREAST ULTRASOUND: NEW TECHNIQUES

- **Elastography**
- 3-D Ultrasound Imaging



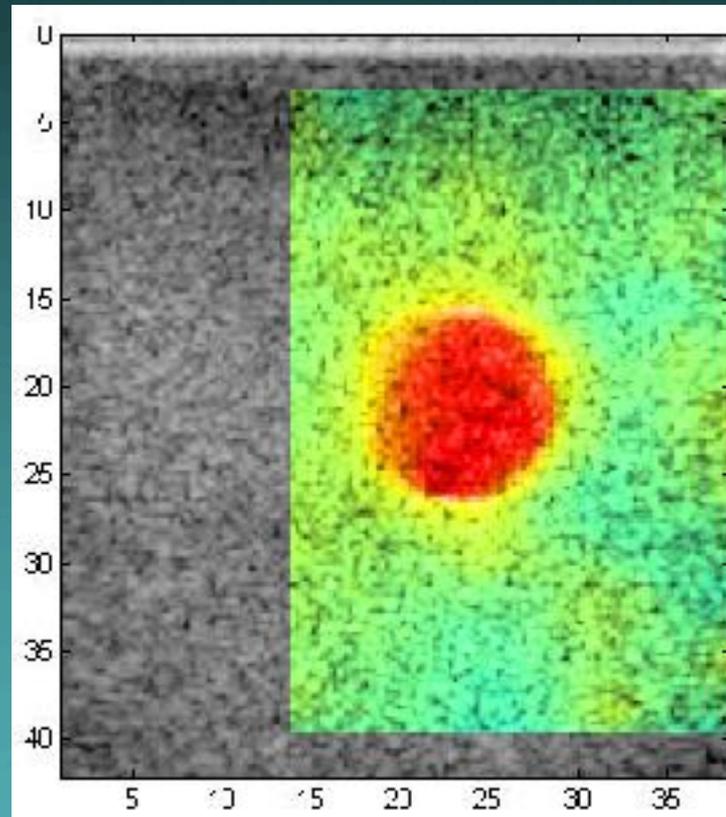
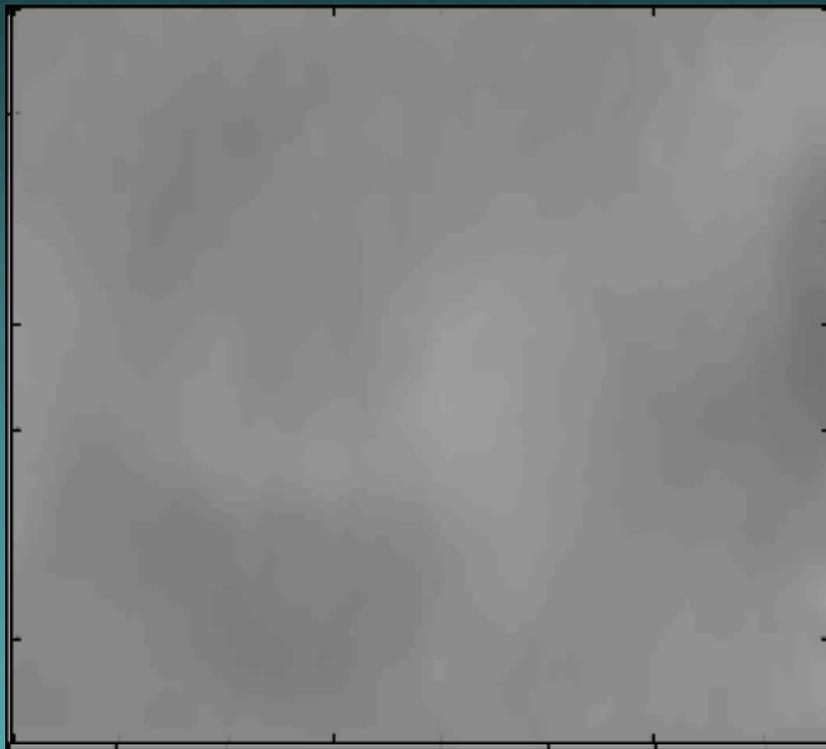
WHAT IS ELASTOGRAPHY?

→ METHODOLOGY:

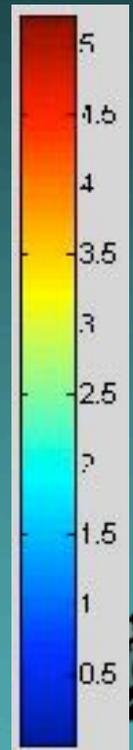
- Mechanical force induced to tissue (external or internal force)
- Measurements of tissue displacements (with US)
- Estimation of tissue stiffness- Qualitative (strain) or Quantitative (estimation)

THE TECHNOLOGY

- ShearWave Elastography Mode
- Mechanical constraint generated by acoustic pulse (user-independent and reproducible)



kPa

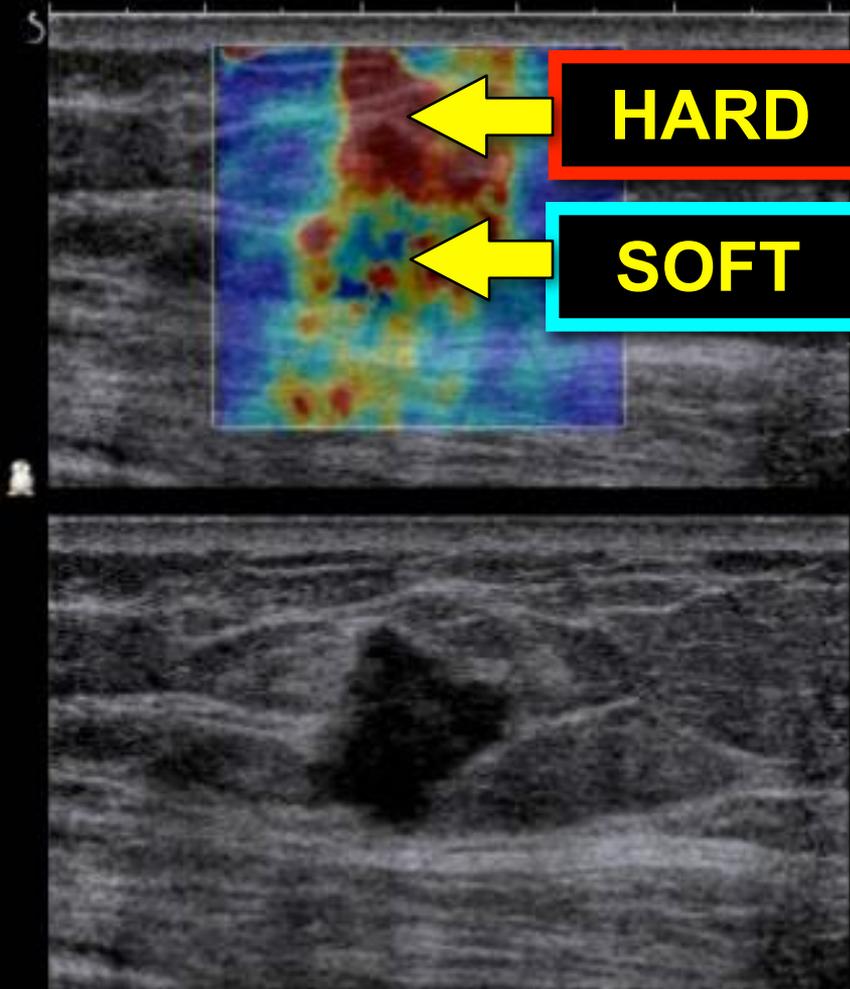


2D

Tissue -1
Gen / Gen
Map 1 / 52 dB
Gain 36 %

E

Gen
Map 1
Transp. 35 %
Persist. 5
Smooth. 4
Gain 75 %



HARD

SOFT

+180 KPa

144

108

72

36

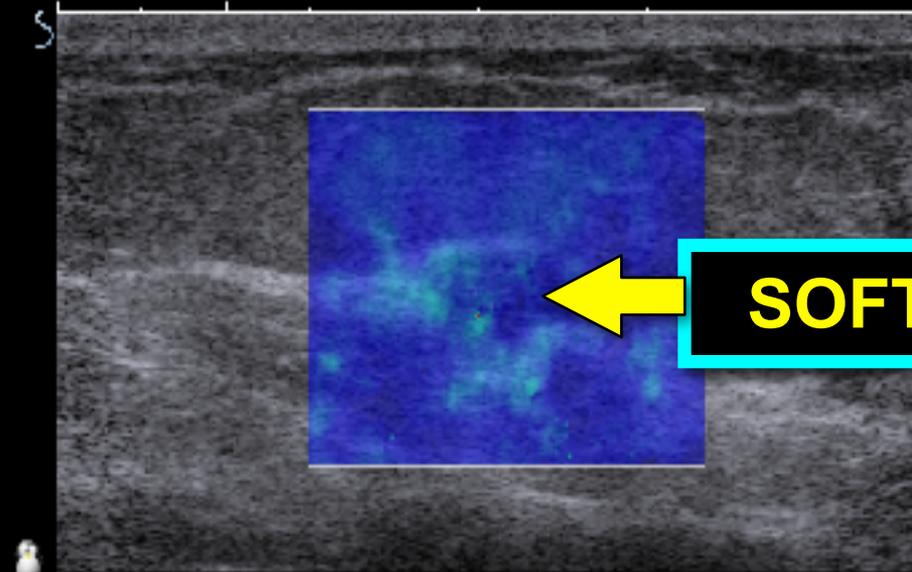
0

INVASIVE DUCTAL CARCINOMA, GRADE 2

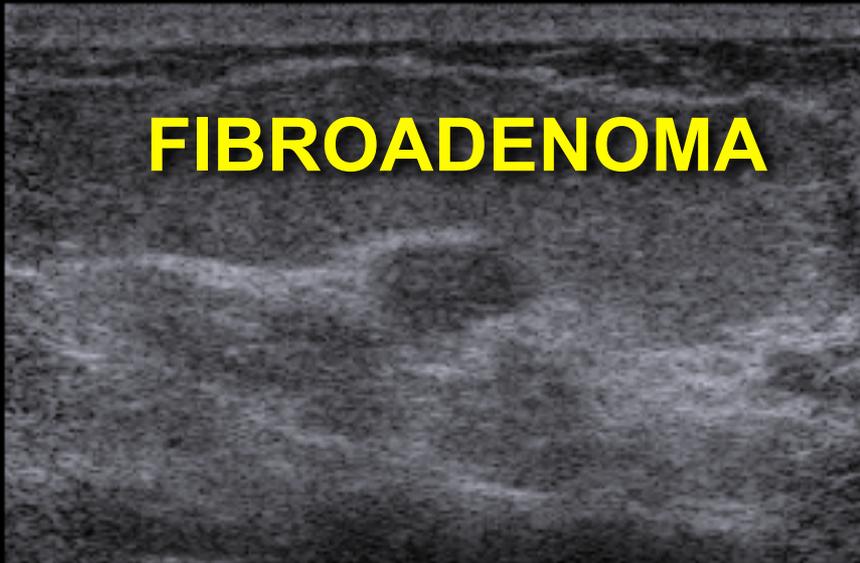


35.0 -1
en/Gen
ap 2.752 dB
a.148 %

en
ap
comp 60.96
ersist 0
room /
a.175 %



SOFT



FIBROADENOMA





BREAST ULTRASOUND: NEW TECHNIQUES

- Elastography
- 3-D Ultrasound Imaging



3D ULTRASOUND: APPLICATIONS

- **Showing spiculation better**
- **Distinguishing artifactual shadowing from a shadowing malignancy**
- **Showing DCIS components and intraductal components**
- **Assessing complex cysts**
- **Identifying anatomy**



3D ULTRASOUND: APPLICATIONS

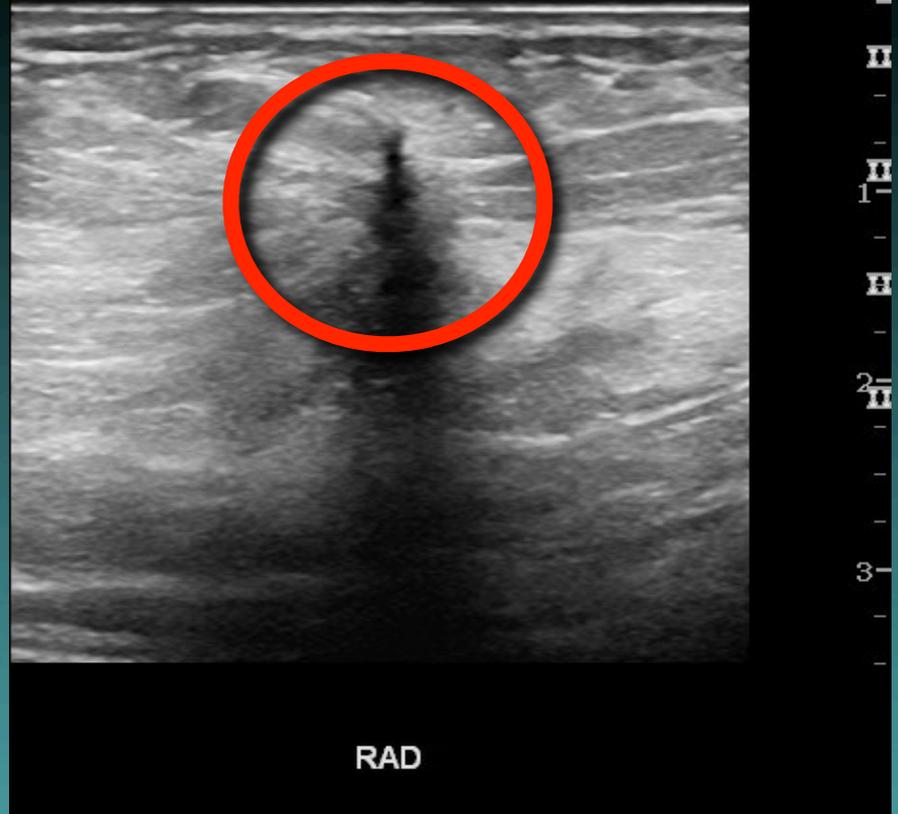
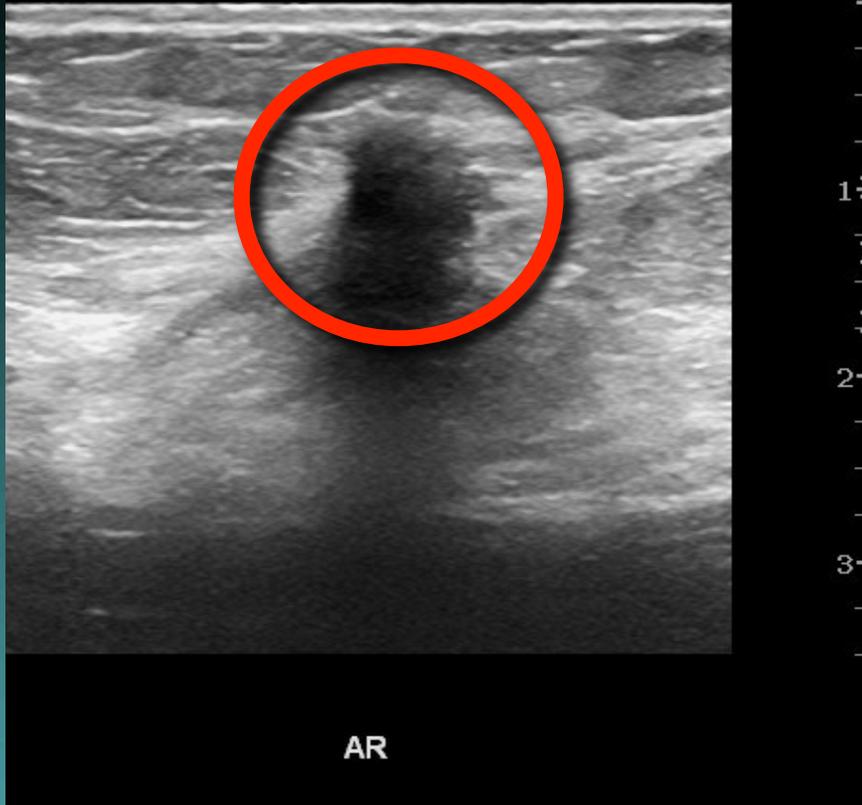
- Showing spiculation better



3D ULTRASOUND FOR SPICULATIONS

- **Spicules are best seen in the CORONAL plane**
- The path of low resistance for invasion is the coronal plane
- Spicules more numerous & prominent within tissue planes of the breast, which are **coronally** oriented
- 3D imaging in the coronal plane shows spicules very well

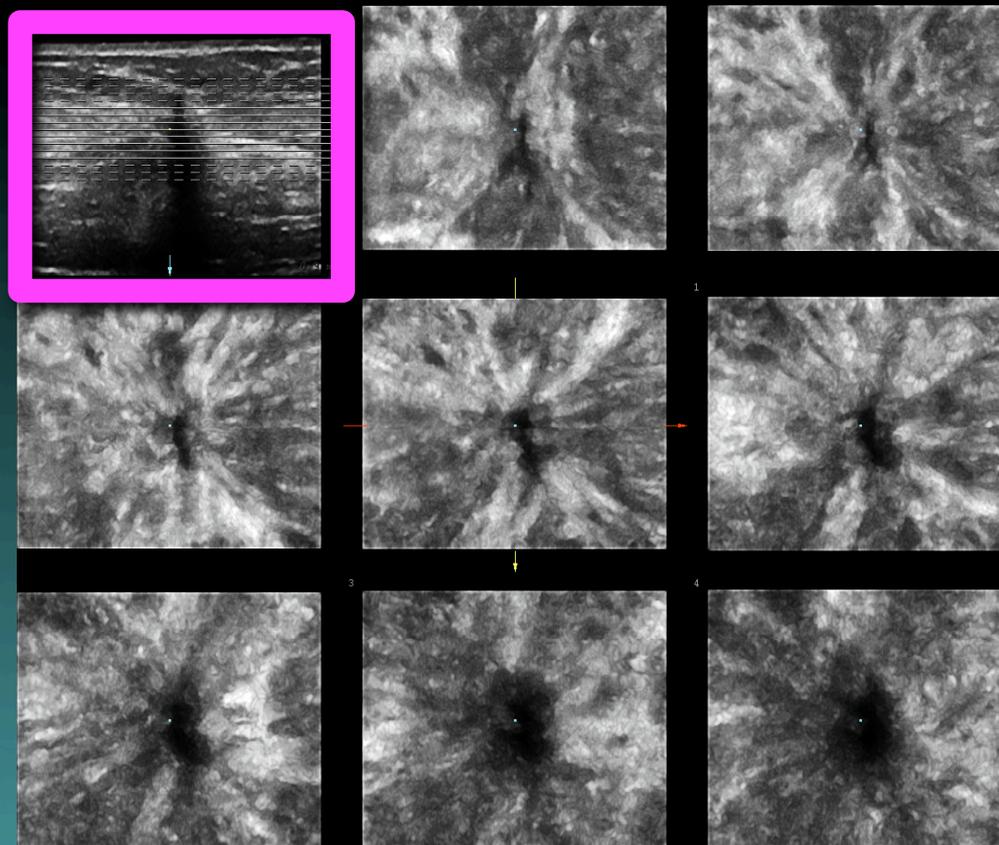
2D ULTRASOUND



Courtesy Dr. Tom Stavros



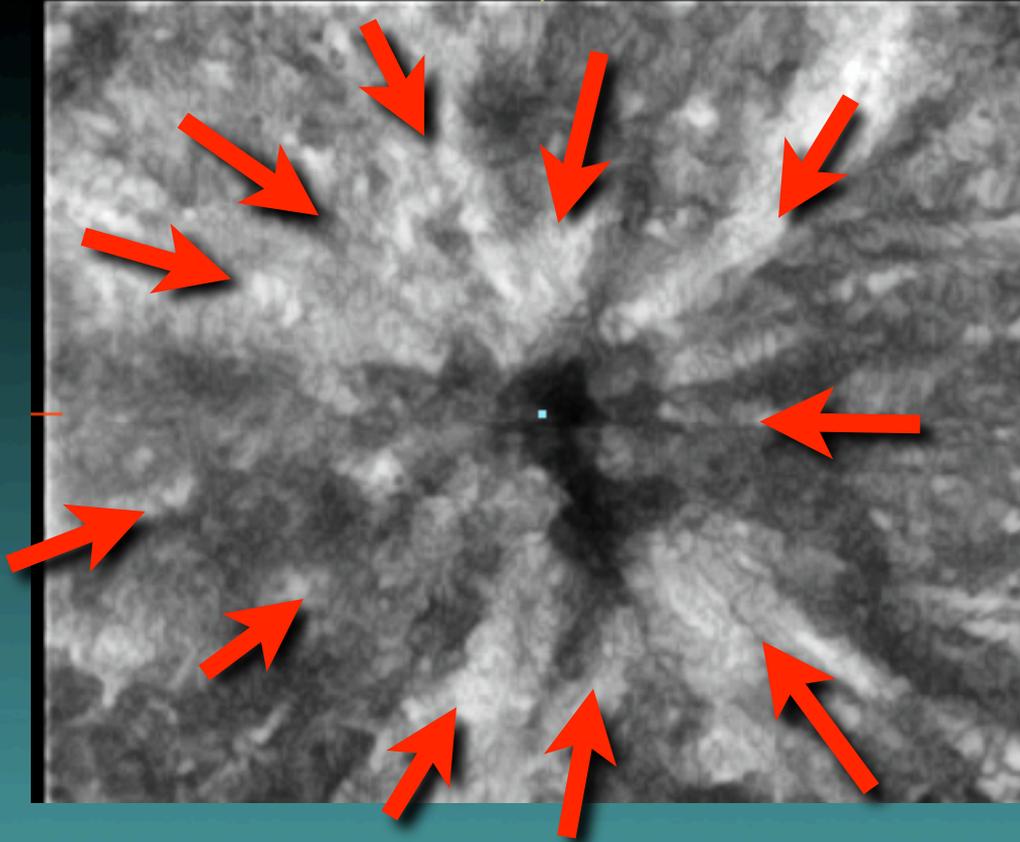
3D ULTRASOUND: SAME LESION



Courtesy Dr. Tom Stavros



3D ULTRASOUND: SAME LESION

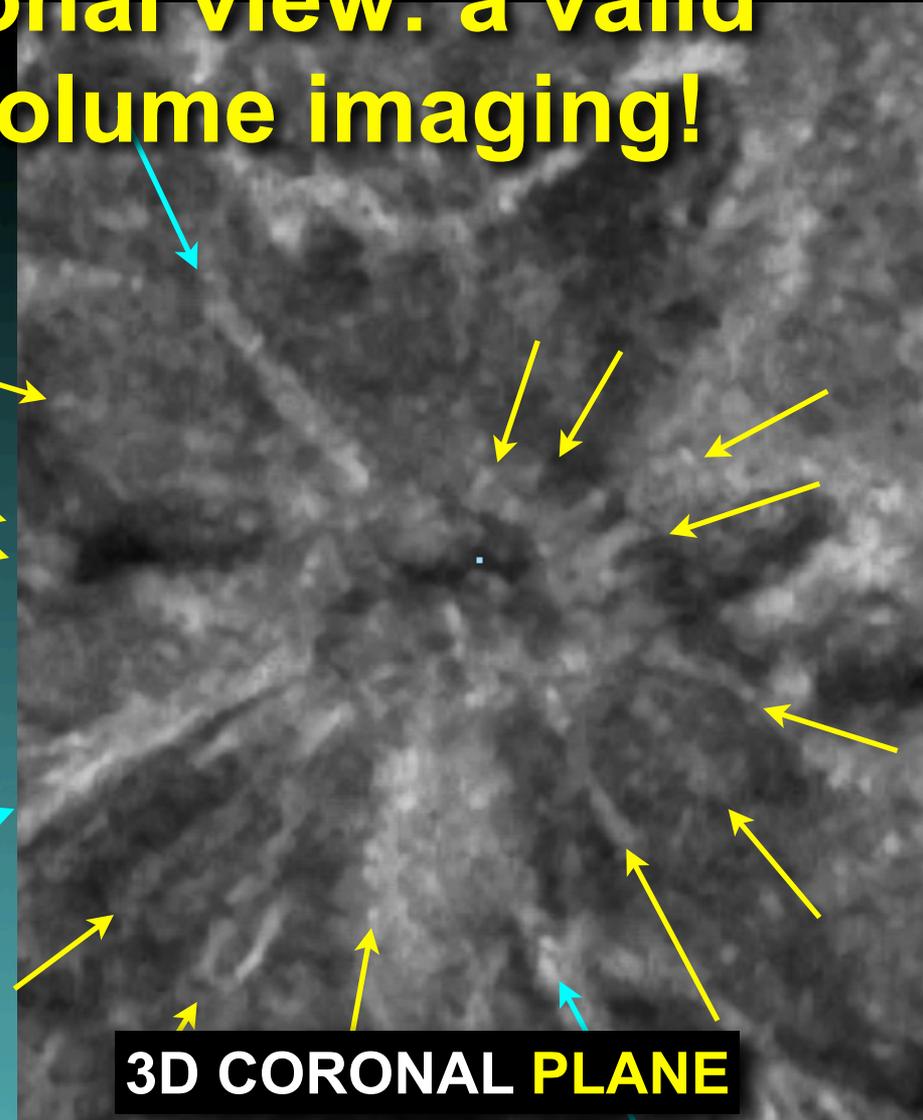
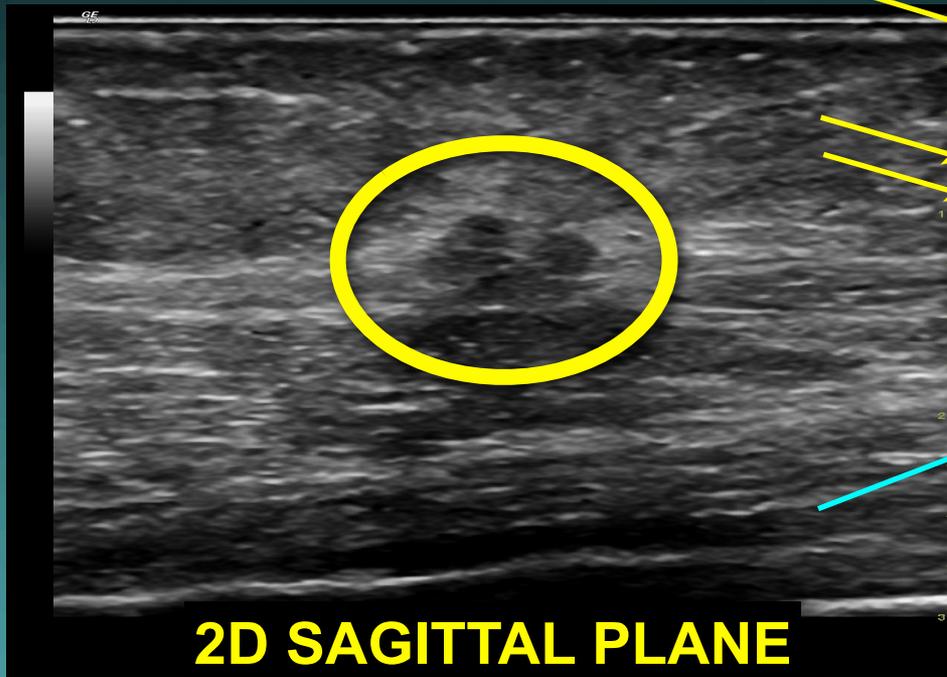


Most spicules hyperechoic & superficial

Courtesy Dr. Tom Stavros



Sometimes, spiculations are seen ONLY on the coronal view: a valid argument for volume imaging!



Courtesy Dr. Tom Stavros



NEW TOOLS IN BREAST IMAGING

- Full Field Digital Mammography
 - Tomosynthesis, Digital Subtraction
- Optical Scanning
 - Thermography, Opto-Acoustic Imaging
- Ultrasound
 - Elastography, 3D Ultrasound
- Artificial Intelligence
 - For Mammography and Tomosynthesis

WHAT IS AI?

Development of computer systems able to perform tasks that normally require human intelligence



ARTIFICIAL INTELLIGENCE

techniques that enable computers to mimic human intelligence

MACHINE LEARNING

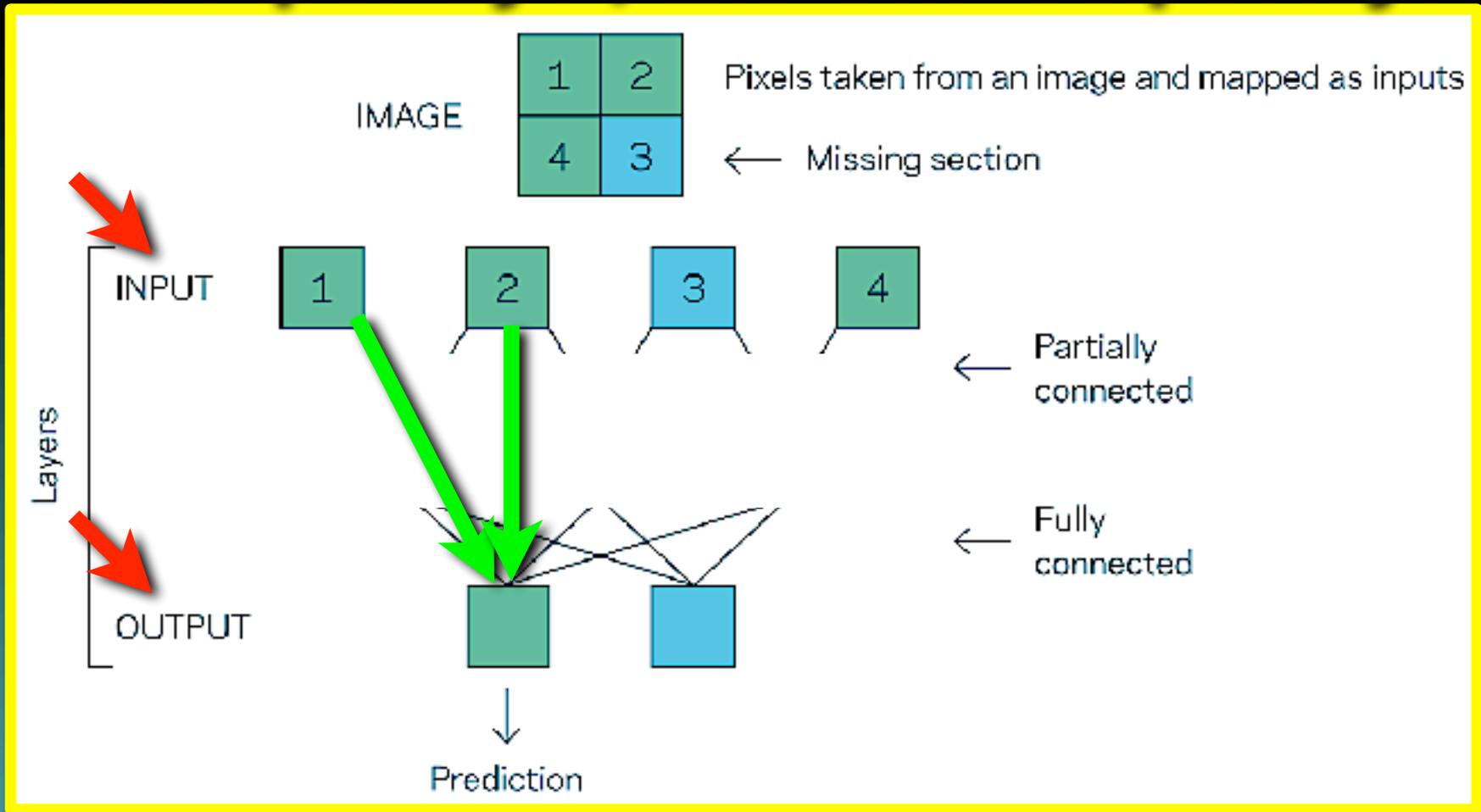
techniques where machines improve at tasks with experience

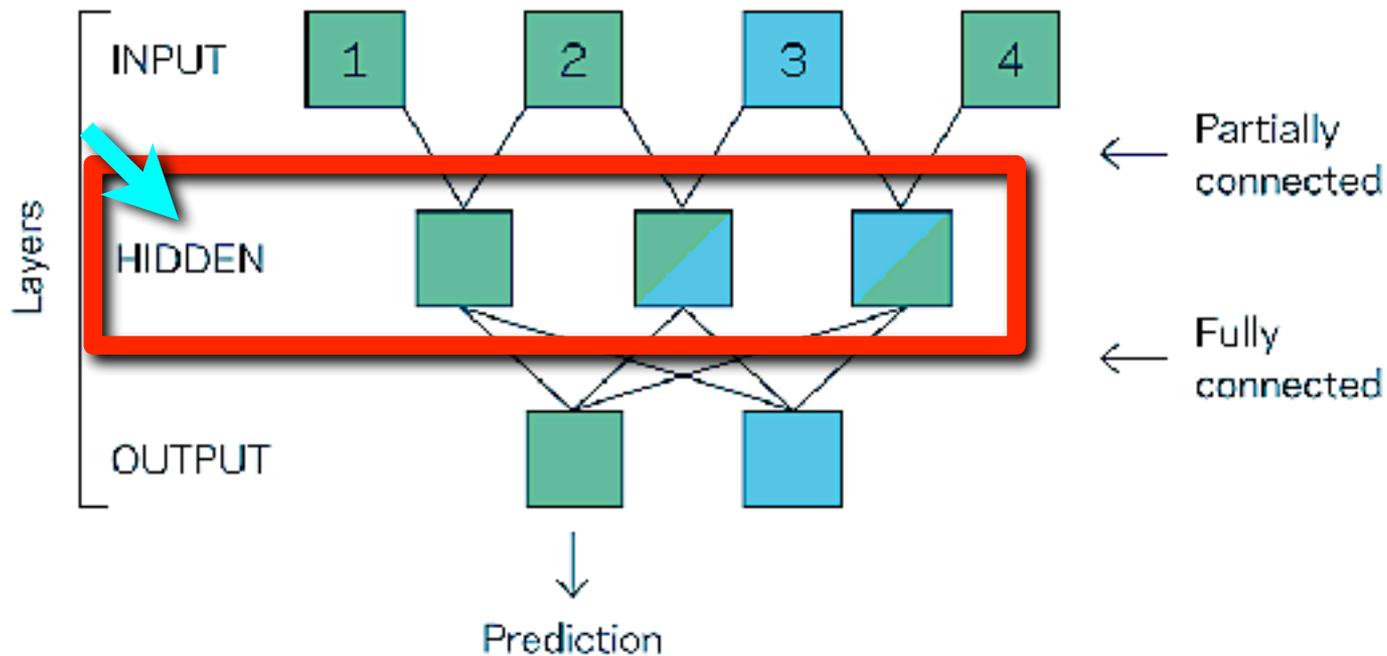
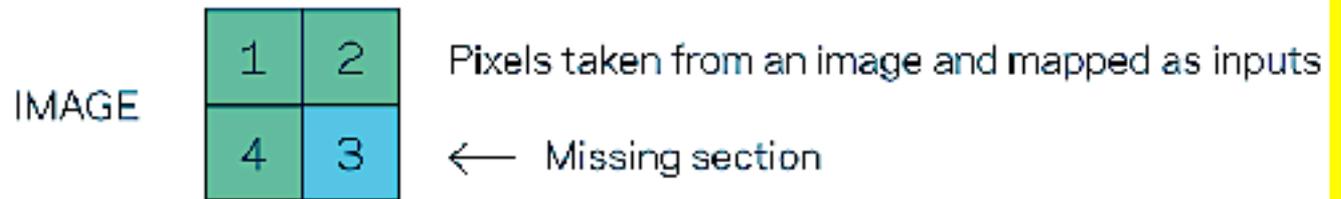
DEEP LEARNING

*machine learning using deep neural networks
(inspired by human brain architecture)*

Machine Learning: Neural Network

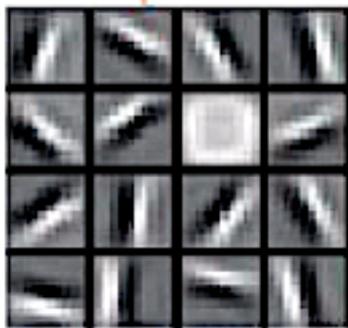
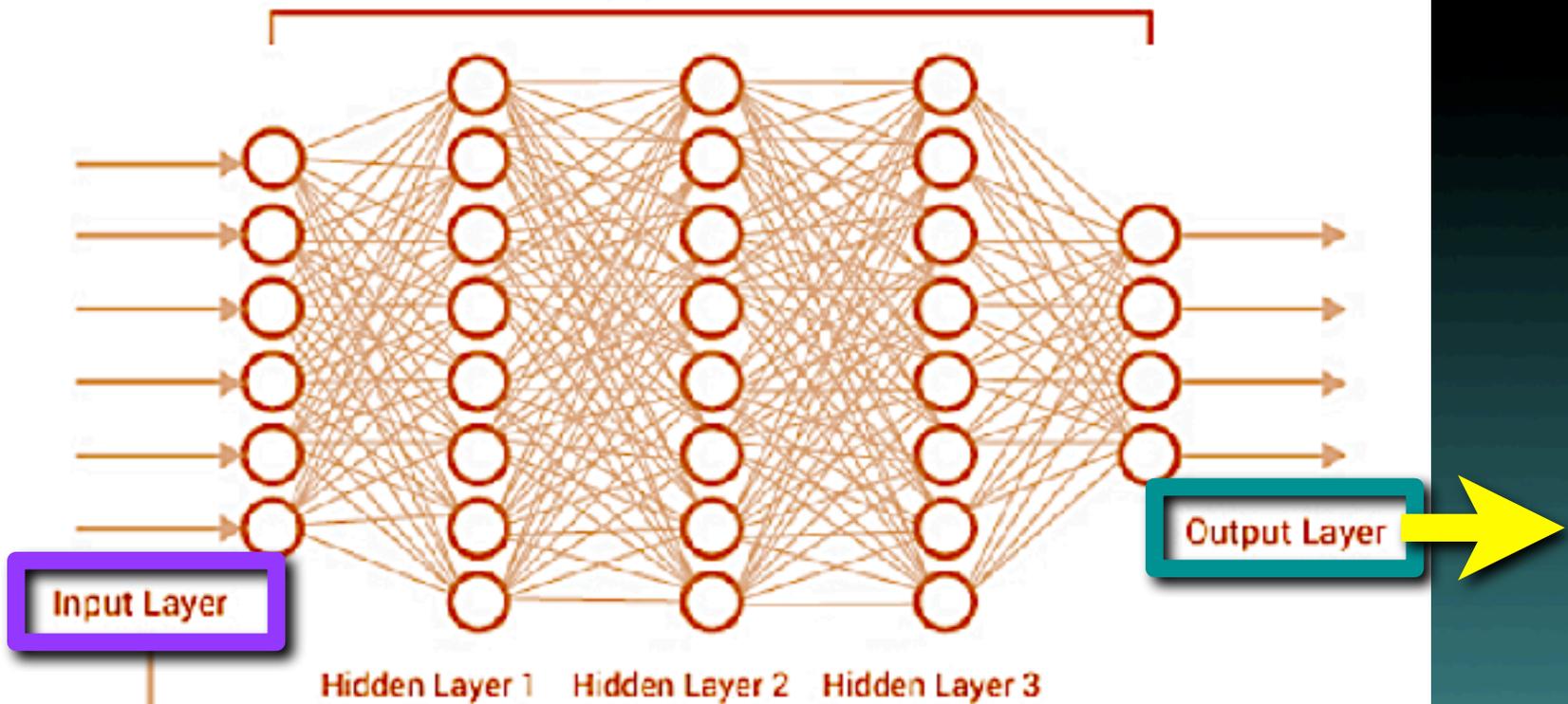
One input layer, and One Output layer





DEEP Learning: At least 2 other Hidden Neural Network layers in between

Deep Neural Network



edges



combinations of edges



object models



AI APPLICATION FOR SKIN CANCER DETECTION

Image of skin lesion

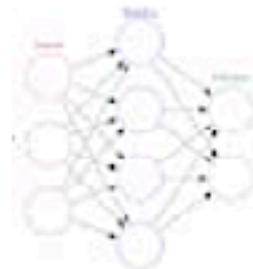
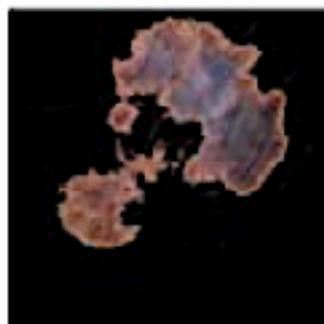
Segmented lesion

Learning Model

Prediction



Benign



Malignant

Kalouche S. Vision-Based Classification of Skin Cancer Using Deep Learning. Stanford University.



AI APPLICATIONS IN BREAST IMAGING

- CAD
- FIRST READ OF SCREENING MAMMOGRAMS
- SYNTHETIC 2D MAMMOGRAPHY
- BREAST DENSITY CATEGORIZATION FOR BREAST CANCER RISK



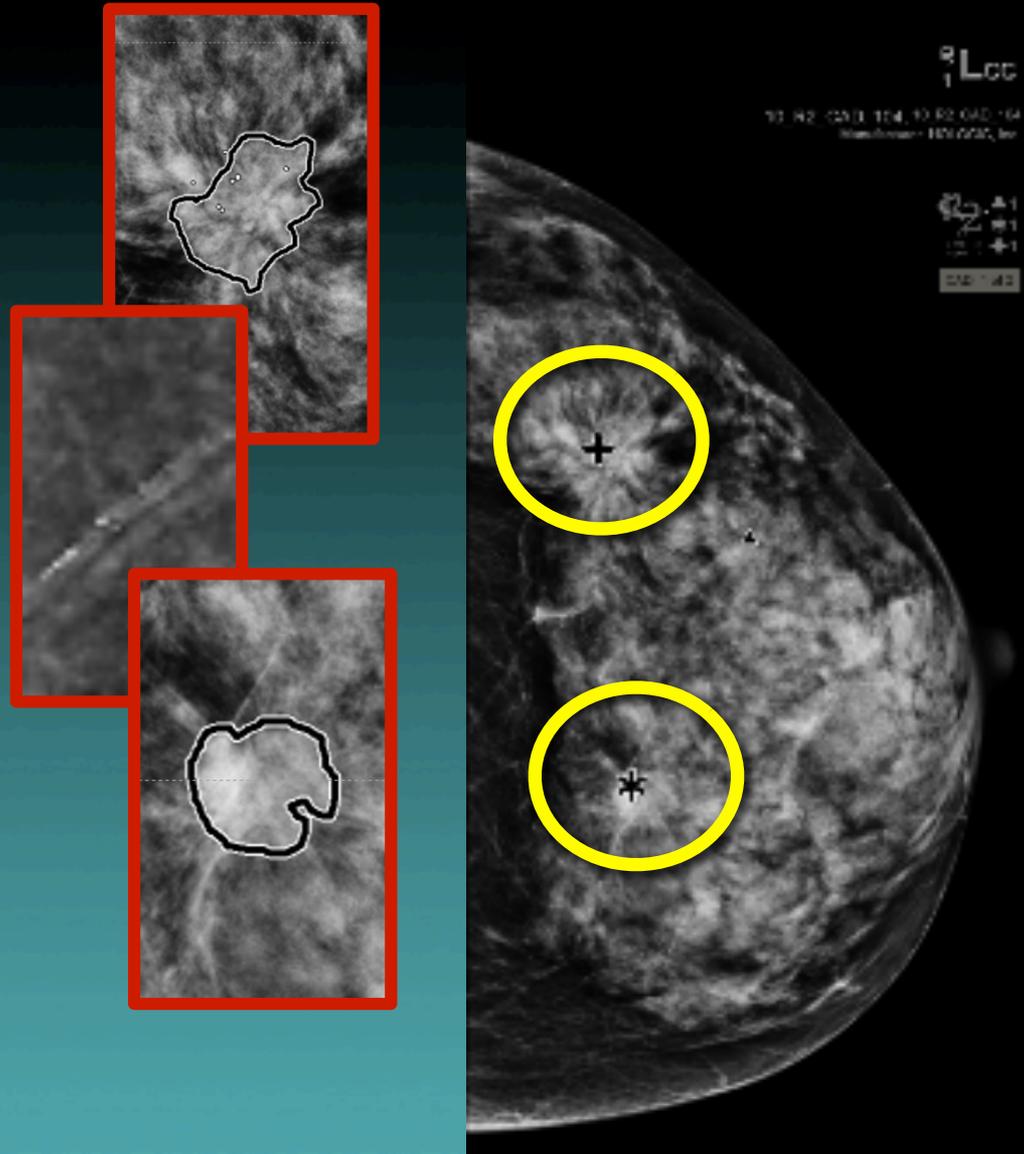
AI APPLICATIONS IN BREAST IMAGING

→ CAD

- FIRST READ OF SCREENING MAMMOGRAMS
- SYNTHETIC 2D MAMMOGRAPHY
- BREAST DENSITY CATEGORIZATION FOR BREAST CANCER RISK

AI APPLICATIONS IN BREAST IMAGING

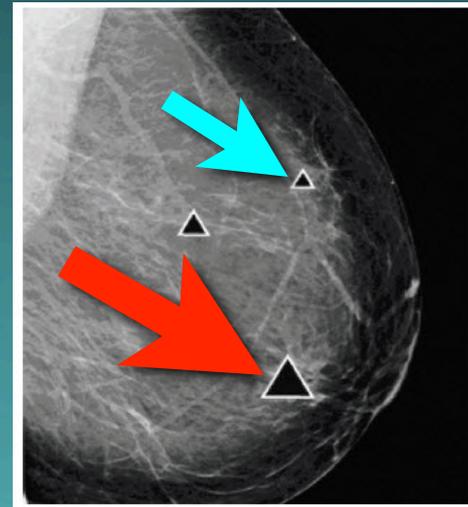
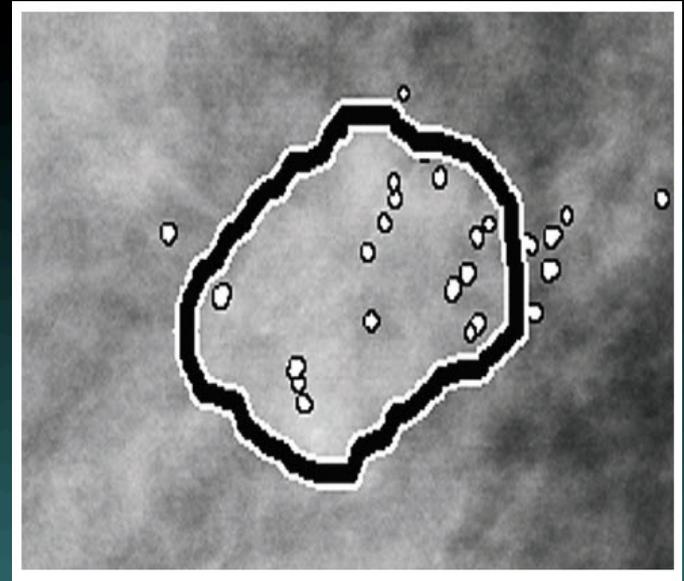
CAD systems-
Constantly
improving
over the past
20 years



AI APPLICATIONS IN BREAST IMAGING

CAD systems- Now very sophisticated:

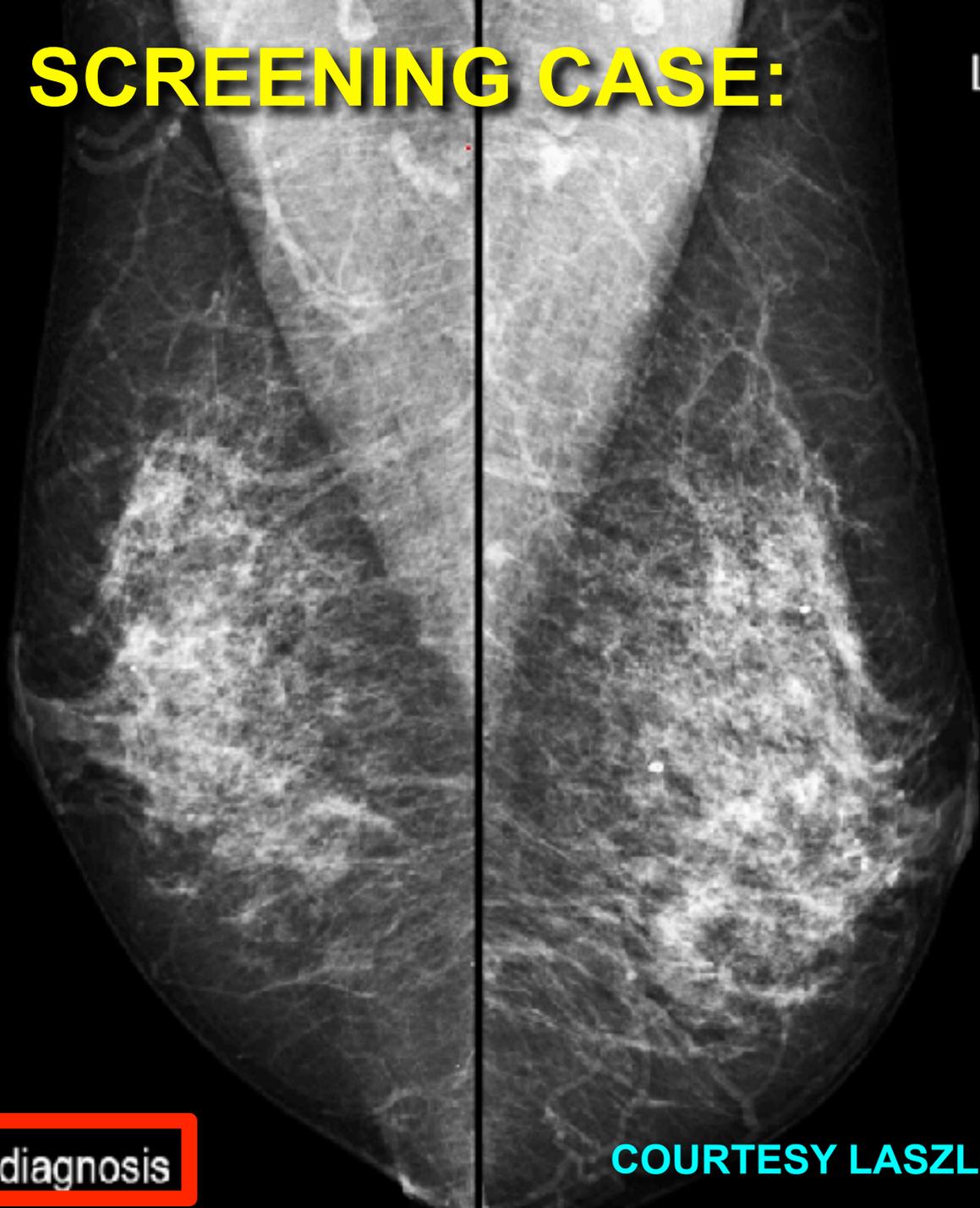
Markings are sized according to the likelihood of malignancy!



Right MLO

SCREENING CASE:

Left MLO



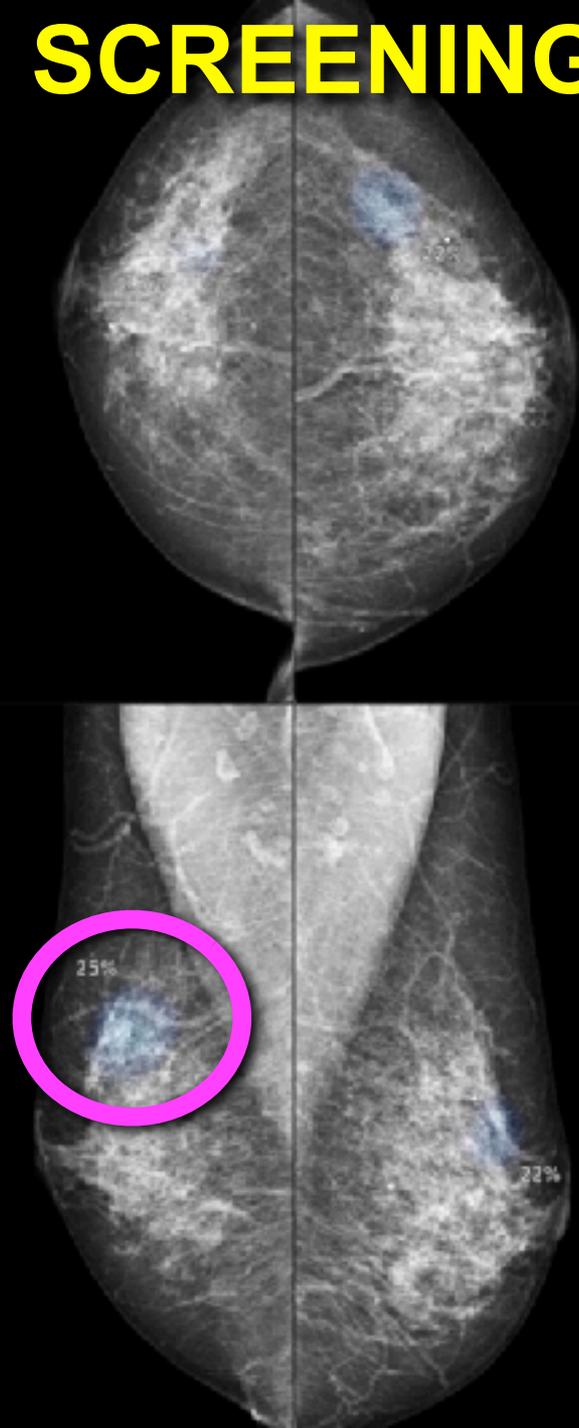
62 months prior to diagnosis

COURTESY LASZLO TABAR

SCREENING CASE:

AI

WITH AI

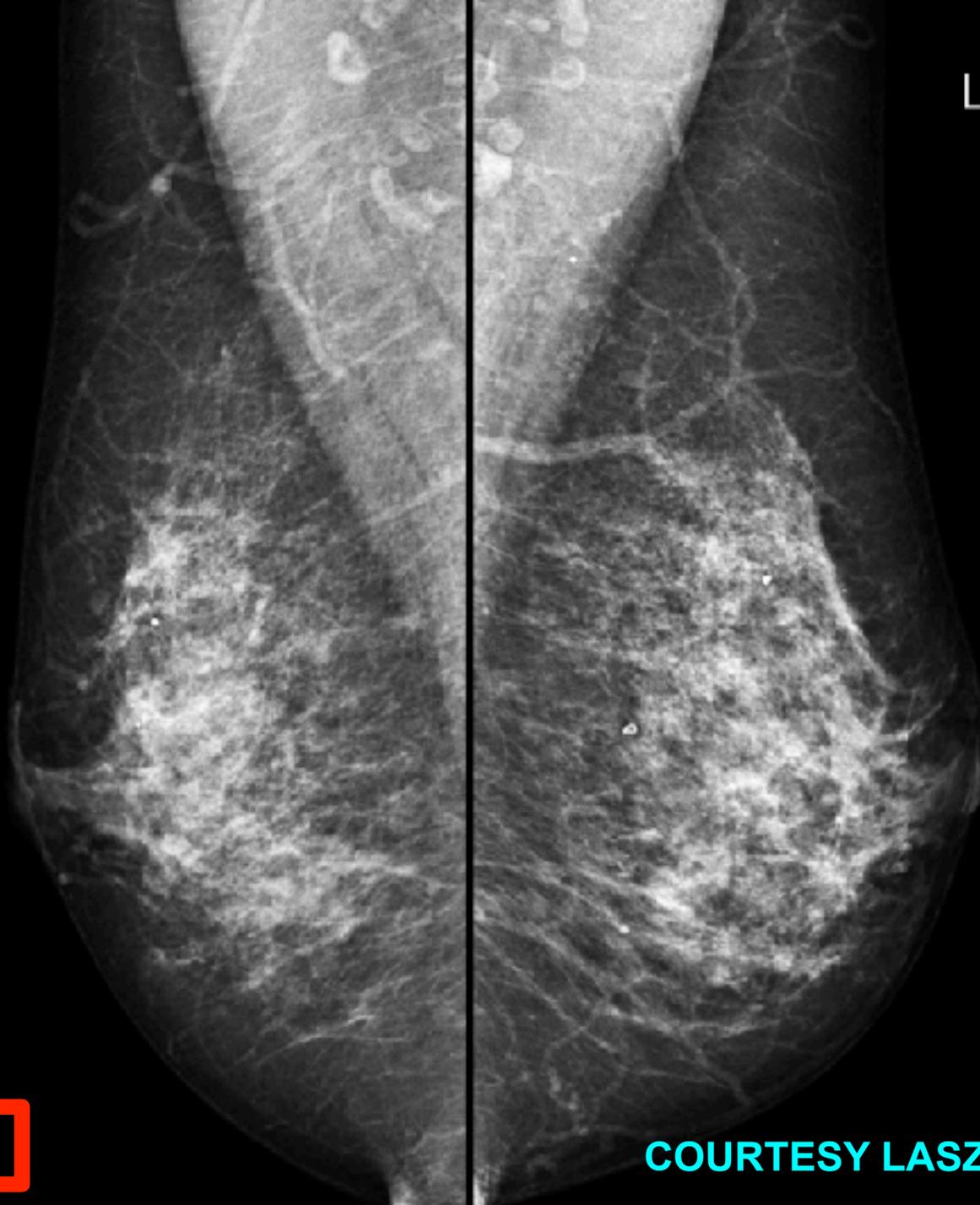


62 months prior to diagnosis



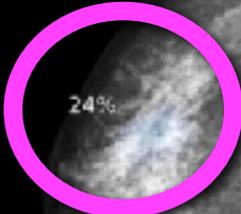
Right ML

Left MLO



25 months later

COURTESY LASZLO TABAR

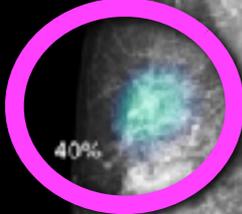


24%

18%

AI

WITH AI



40%

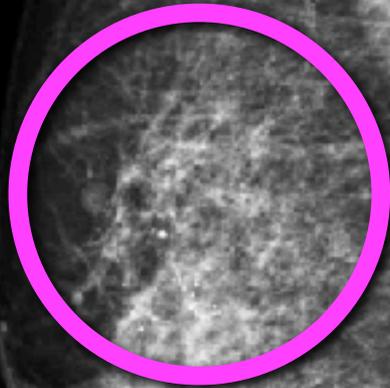
25 months later

COURTESY LASZLO TABAR



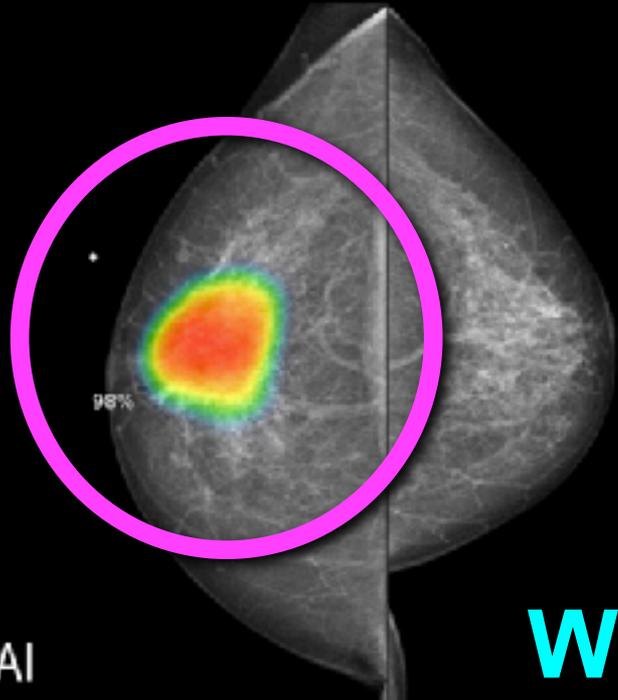
Right MLO

Left MLO



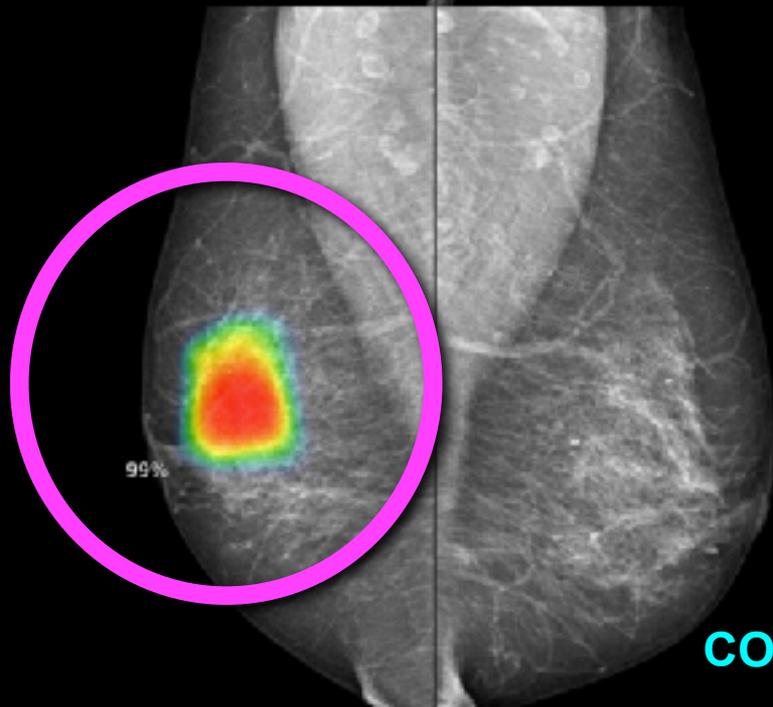
37 months later
At the time of diagnosis and treatment

COURTESY LASZLO TABAR



AI

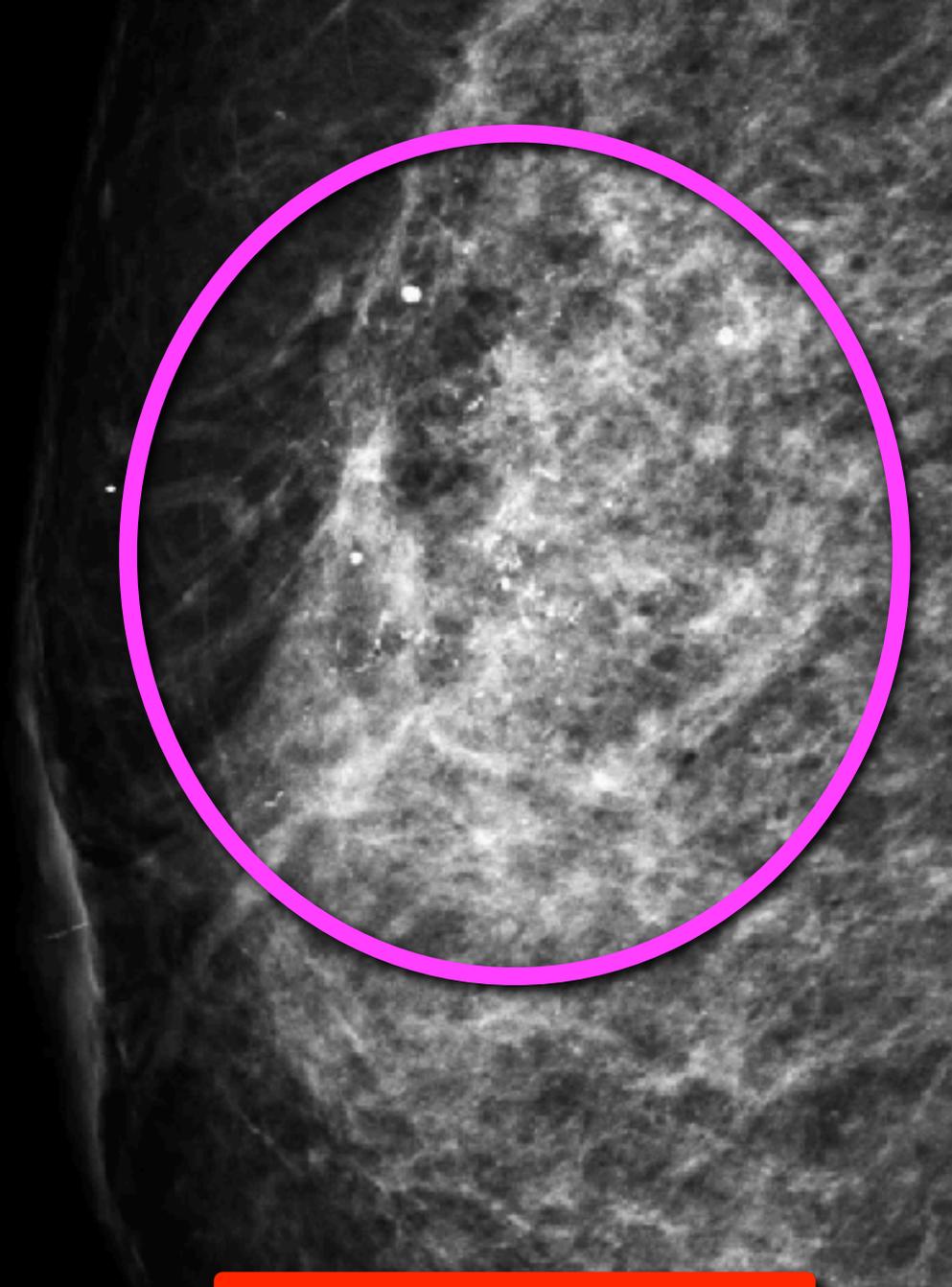
WITH AI



COURTESY LASZLO TABAR



Right MLO



Microfocus magnification



MASTECTOMY SPECIMEN

Dx

**5 CM INVASIVE CANCER
WITH ASSOCIATED DCIS**

Mastectomy specimen radiograph

COURTESY LASZLO TABAR





AI APPLICATIONS IN BREAST IMAGING

- CAD
- **FIRST READ OF SCREENING MAMMOGRAMS**
- SYNTHETIC 2D MAMMOGRAPHY
- BREAST DENSITY CATEGORIZATION FOR BREAST CANCER RISK

AI APPLICATIONS IN BREAST IMAGING

Direct interpretation of screening mammograms!

Stand-Alone Artificial Intelligence for Breast Cancer Detection in Mammography: Comparison With 101 Radiologists

Alejandro Rodriguez-Ruiz Kristina Lang Albert Gubern-Merida Mirreille Broeders Gisella Gennaro Paola Clauser Thomas H Helbich Margarita Chevalier Tao Tan Thomas Mertelmeier

Matthew G Wallis Ingvar Andersson Sophia Zackrisson Ritse M Mann Ioannis Sechopoulos

JNCI: Journal of the National Cancer Institute, djy222, <https://doi.org/10.1093/jnci/djy222>

Published:

05 March 2019



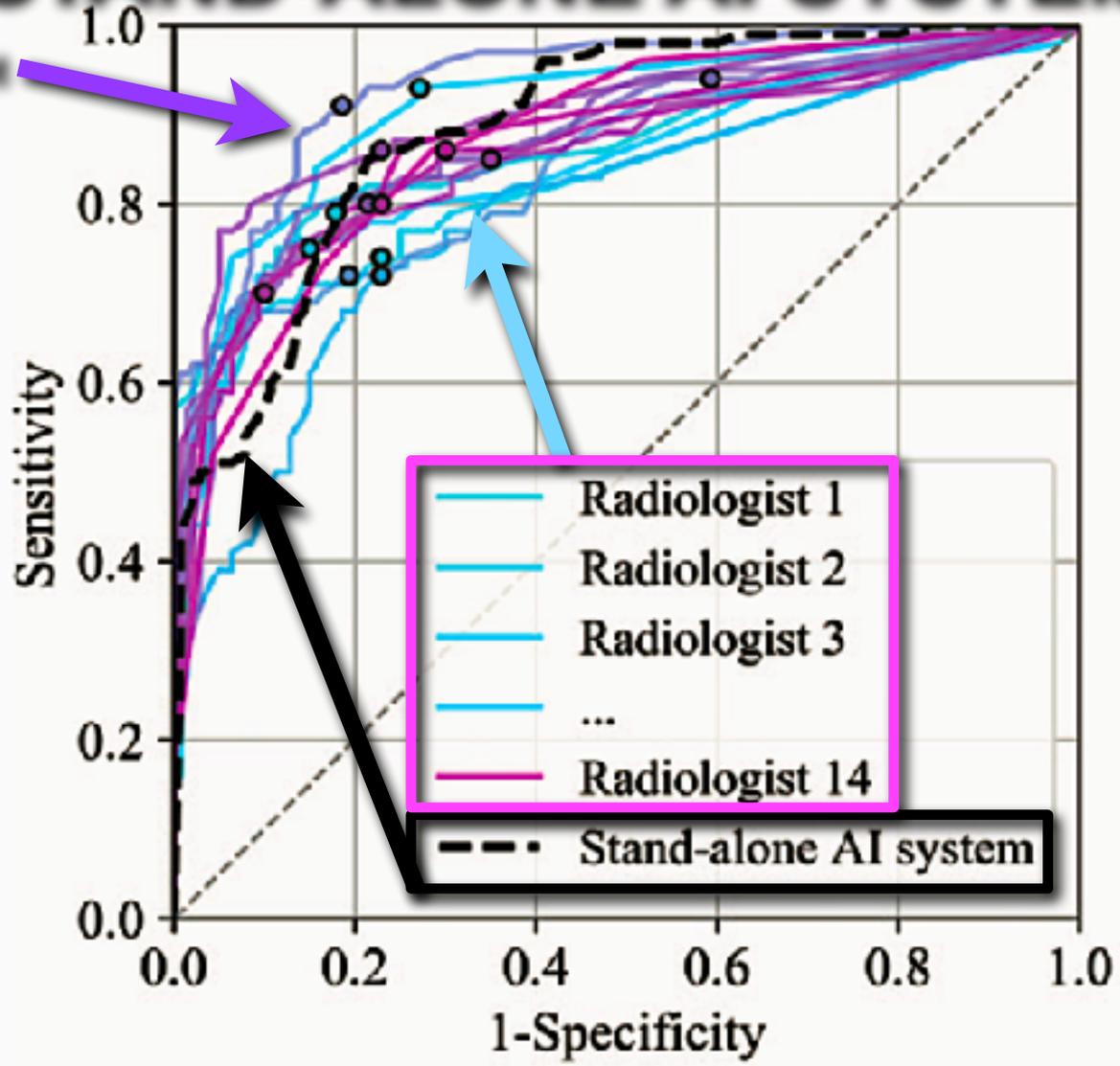


STUDY IN JNCI ON DIRECT AI INTERPRETATION OF MAMMOGRAMS

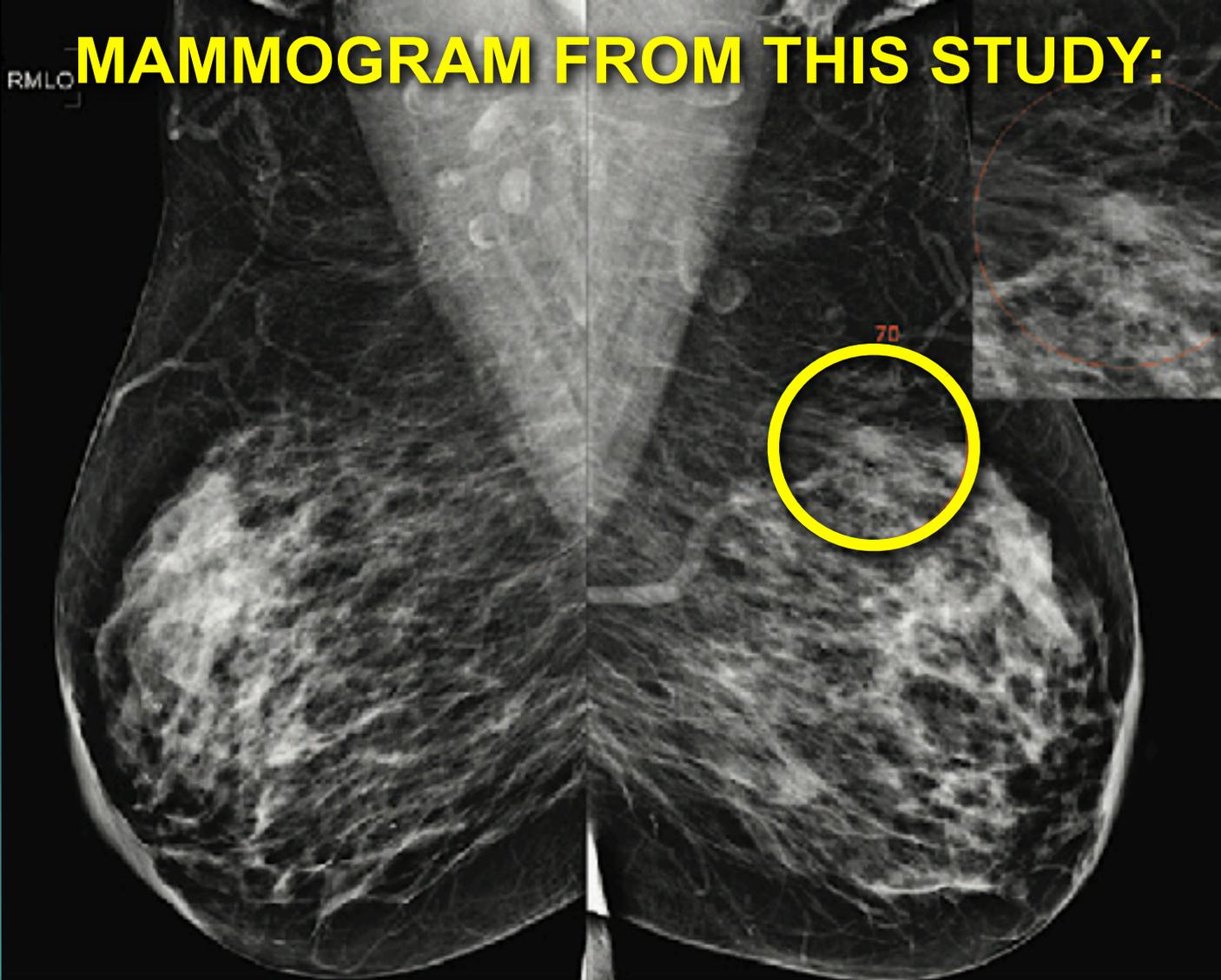
- 101 radiologists interpreted 2652 mammograms (653 malignancies), as did AI
- Each exam given score of 1 to 10 level of suspicion by AI & by radiologists, independently
- ROC Area under curve (AUC, accuracy) **HIGHER FOR AI (.84 versus .81)** than for radiologists
- AI had **higher sensitivity** than 58% of rads!
- AI had **higher AUC** than 62% of radiologists
- **HOWEVER, AI's performance was consistently LOWER** than the **best radiologists**

ROC CURVES OF RADIOLOGISTS VS. STAND-ALONE AI SYSTEM

Best Radiologist



RMLO **MAMMOGRAM FROM THIS STUDY:**



IDC- Found by 4 of 14 radiologists WITHOUT AI
Found by 11 of 14 radiologists WITH AI



STUDY IN JNCI ON DIRECT AI INTERPRETATION OF MAMMOGRAMS

- These findings suggest that AI could be utilized in situations where there is a lack of experienced or specialized breast imagers
- Findings also suggest that AI tuned to a high sensitivity could be utilized to “pre-screen” and eliminate studies deemed to have a very low likelihood of malignancy
- This could reduce radiologists’ workload of cases to be interpreted without impacting their accuracy



AI CAN HELP IN TOMOSYNTHESIS CASES TOO!

- 2025 STUDY: Radiologists interpreted 16,000 tomosynthesis mammograms
- 10,000 interpreted without AI, & 6,000 with AI
- With AI, cancer detection rate TWICE as high as without AI (6.1/1000 vs. 3.7/1000)
- Positive Predictive Value increased from 32% without AI, to 56% with AI
- Therefore AI appears effective in improving radiologists' performance in Tomosynthesis as well



AI APPLICATIONS IN BREAST IMAGING

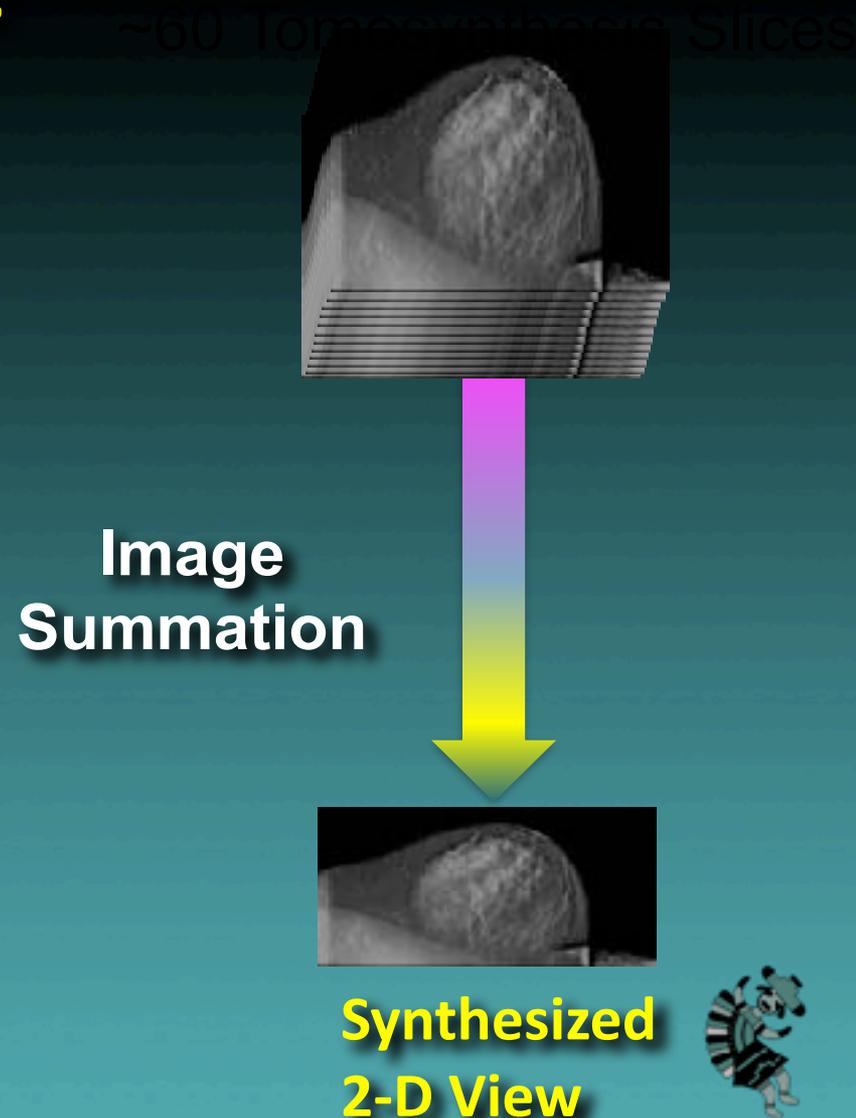
- CAD
- FIRST READ OF SCREENING MAMMOGRAMS
- **SYNTHETIC 2D MAMMOGRAPHY**
- BREAST DENSITY CATEGORIZATION FOR BREAST CANCER RISK

AI APPLICATIONS IN BREAST IMAGING

Synthesized 2D Image

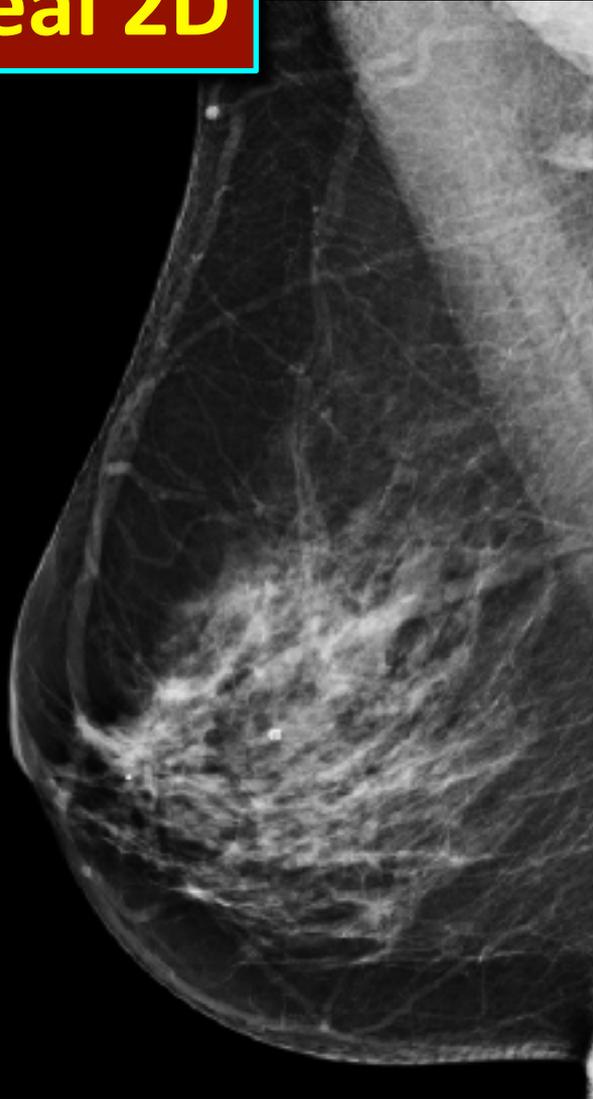
How does it work?

- Perform a standard tomosynthesis scan (existing system)
- Reconstruct tomosynthesis slices (existing system)
- **Synthesize 2D image (C-View)**
 - Similar to Maximum Intensity Projection (MIP) as done with MRI images



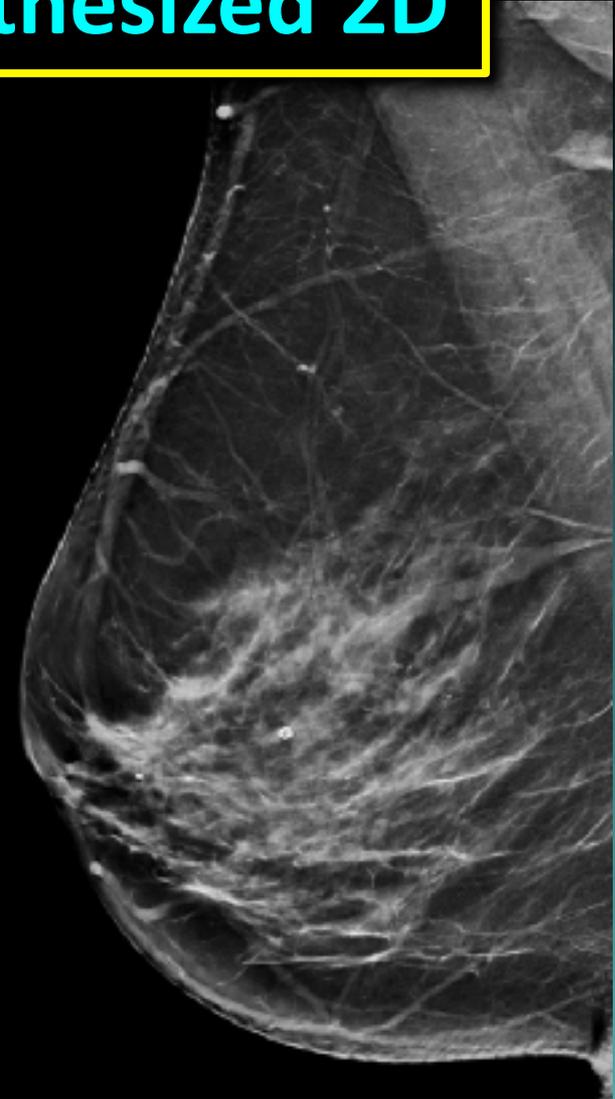
AI APPLICATIONS IN BREAST IMAGING

Real 2D



Synthesized 2D

→ C-View

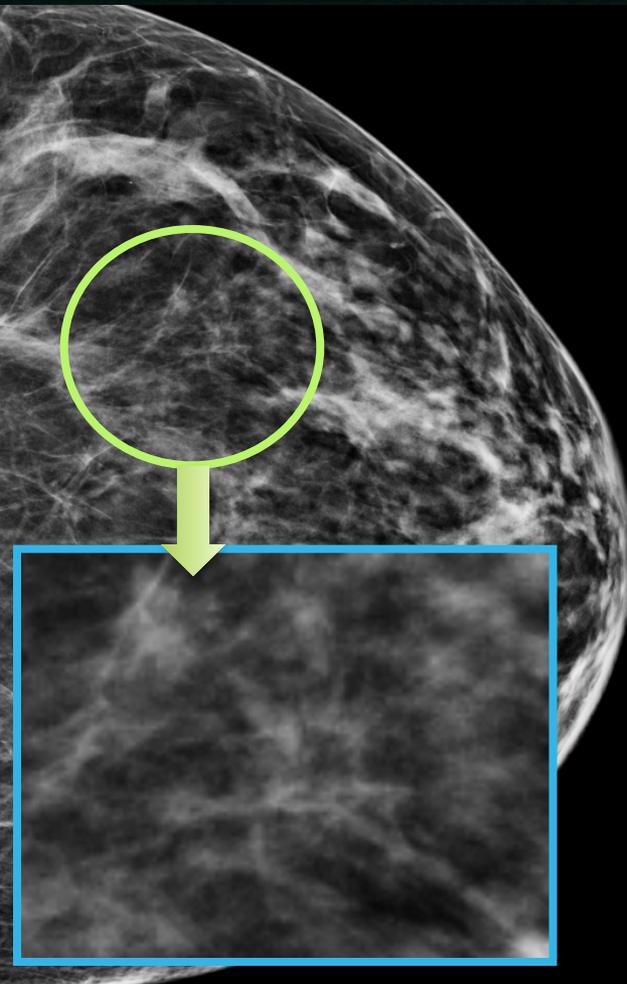


AI APPLICATIONS IN BREAST IMAGING

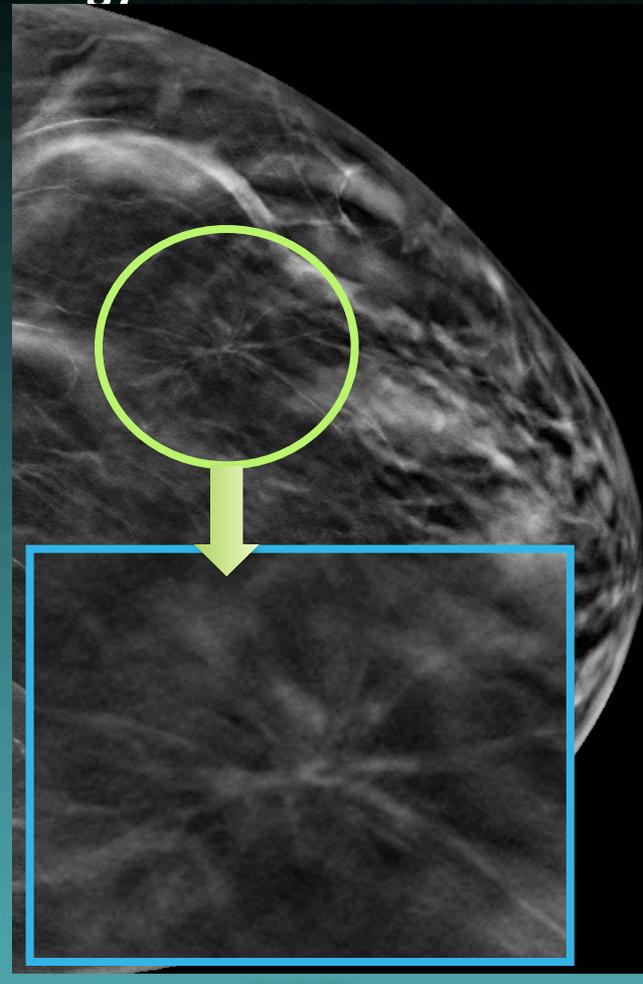
Arch. Distortion on s2D and DBT

51 yo architectural distortion seen well only on s2D/DBT

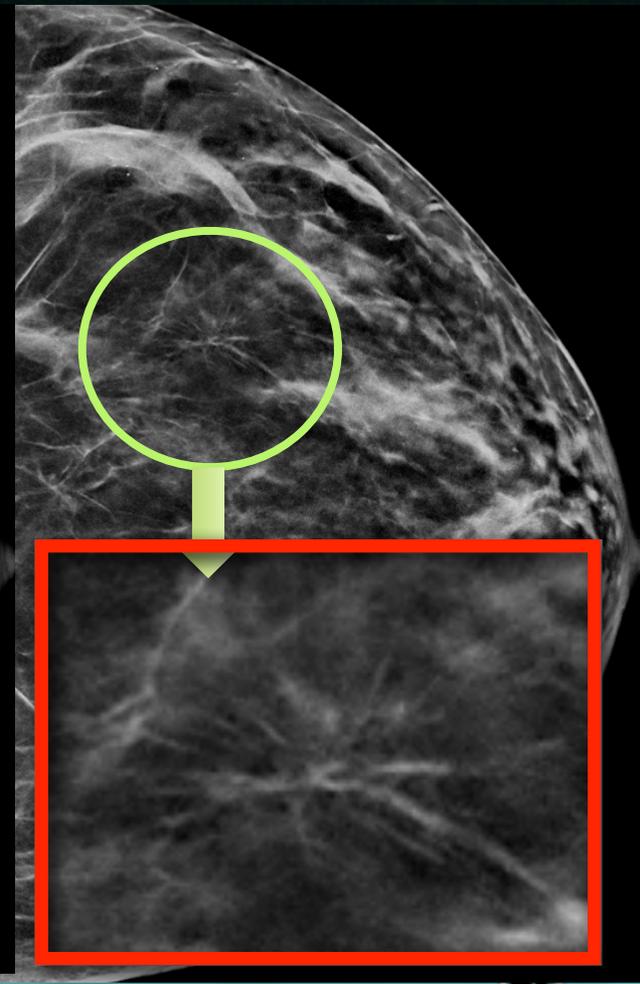
Pathology: invasive ductal carcinoma.



DM



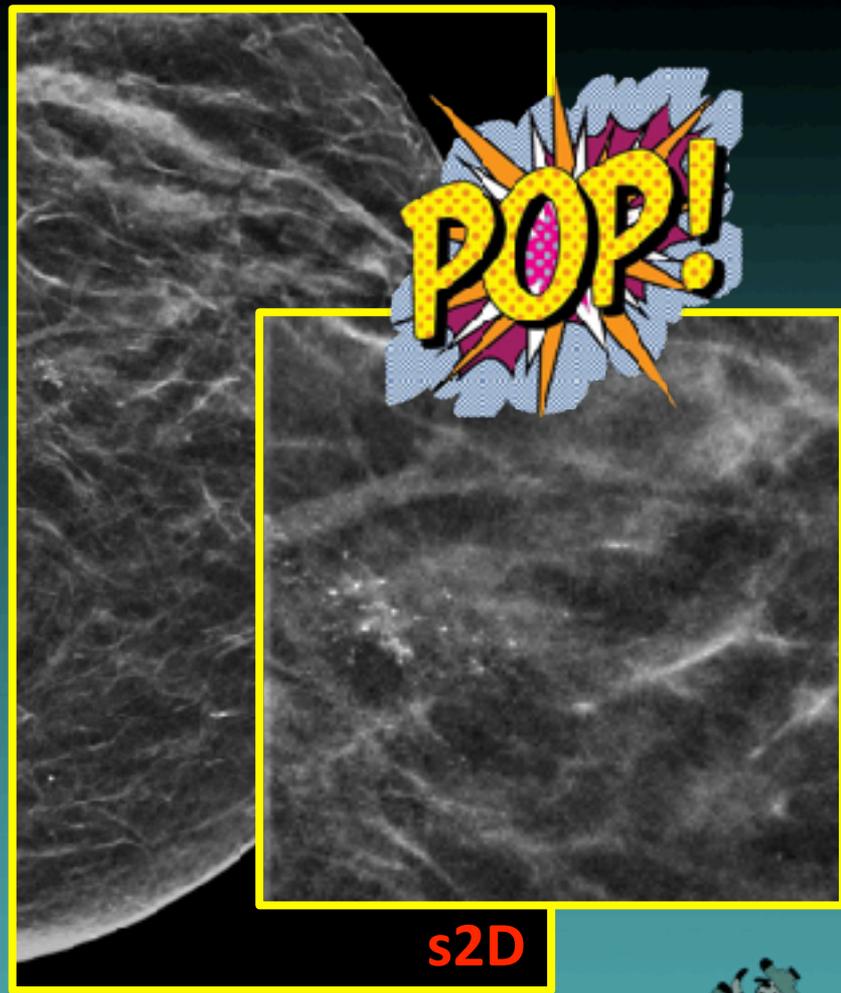
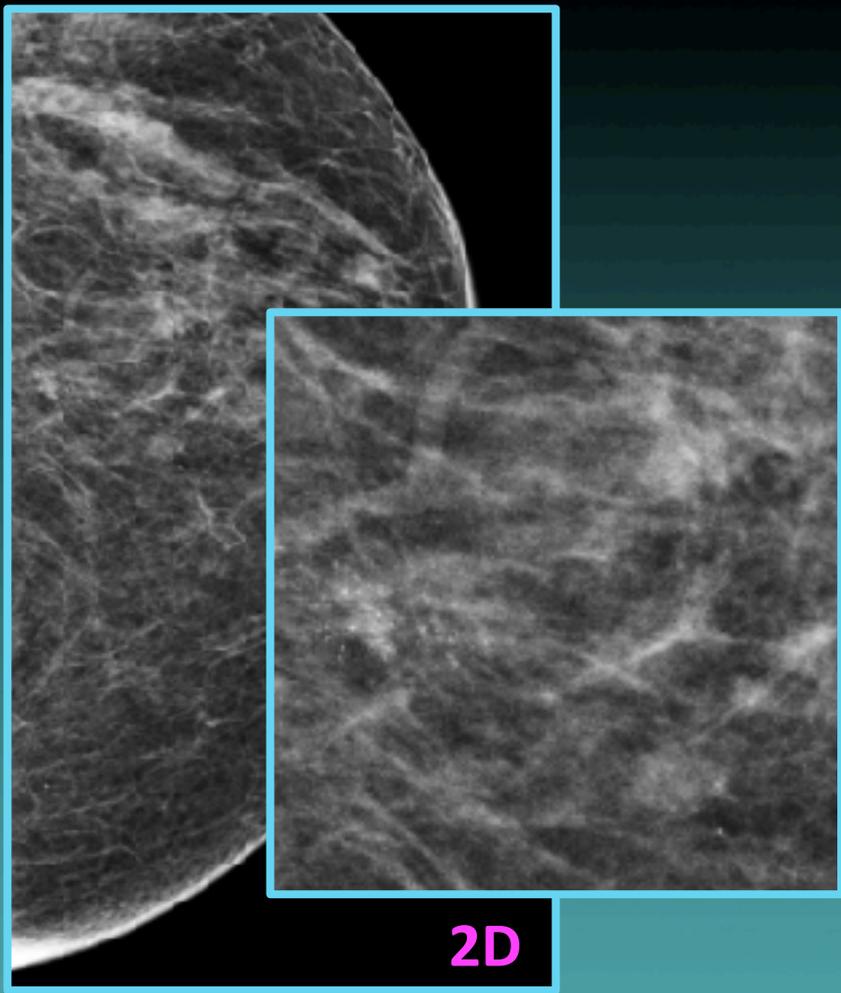
DBT



s2D

AI APPLICATIONS IN BREAST IMAGING

Calc's on Synthetic 2D with Tomosynthesis



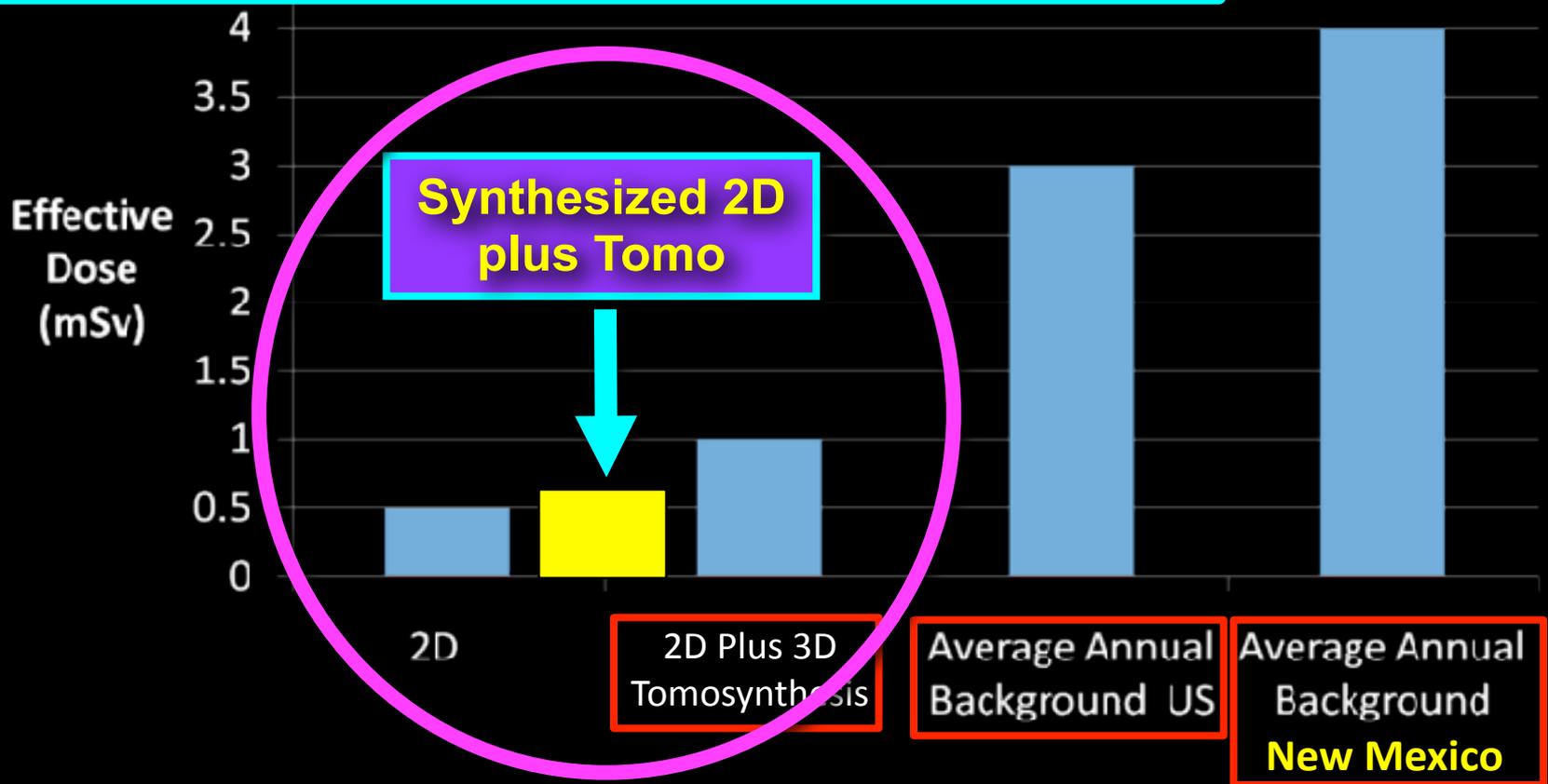
Pathology: Ductal Carcinoma *in situ* (DCIS)



RADIATION DOSE WHEN SYNTHETIC VIEW IS ADDED TO TOMOSYNTHESIS VIEW:

NO ADDED RADIATION DOSE!

Screening Exam

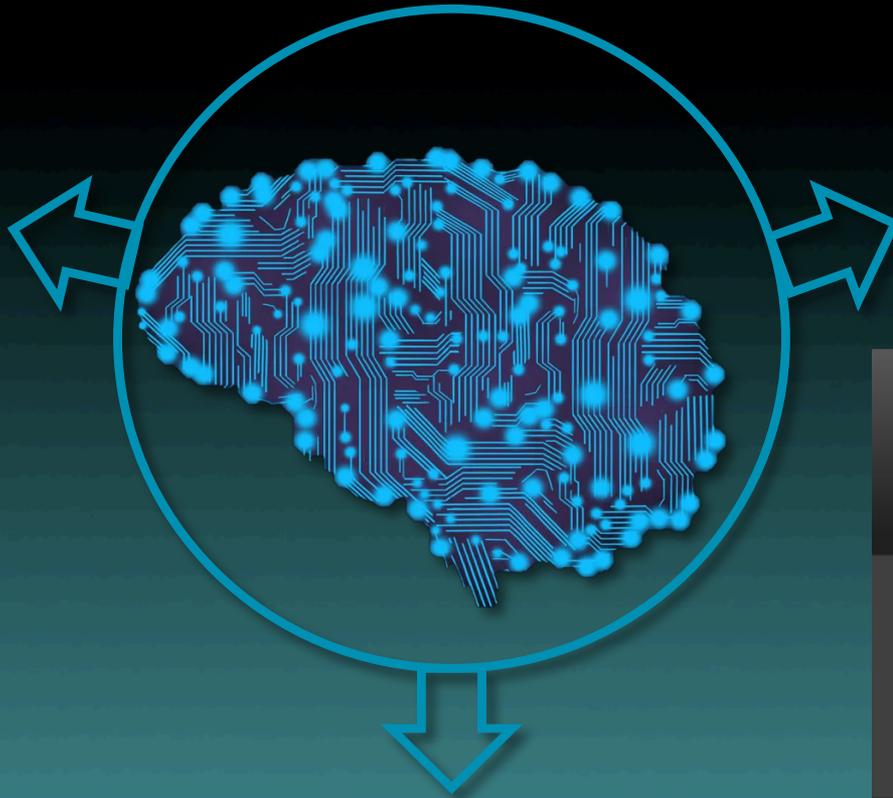




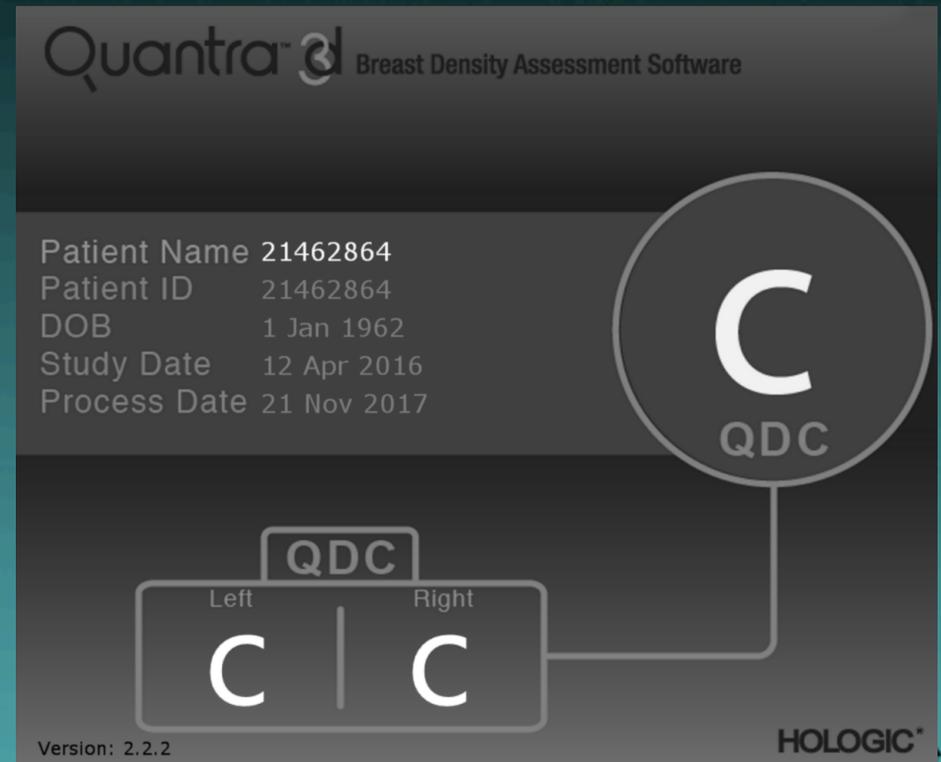
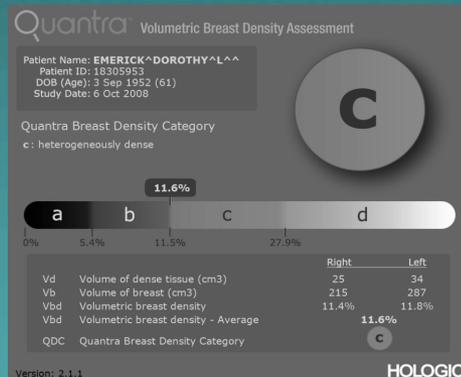
AI APPLICATIONS IN BREAST IMAGING

- CAD
- FIRST READ OF SCREENING MAMMOGRAMS
- SYNTHETIC 2D MAMMOGRAPHY
- **BREAST DENSITY CATEGORIZATION FOR
BREAST CANCER RISK**

AI APPLICATIONS IN BREAST IMAGING



Breast density categorization

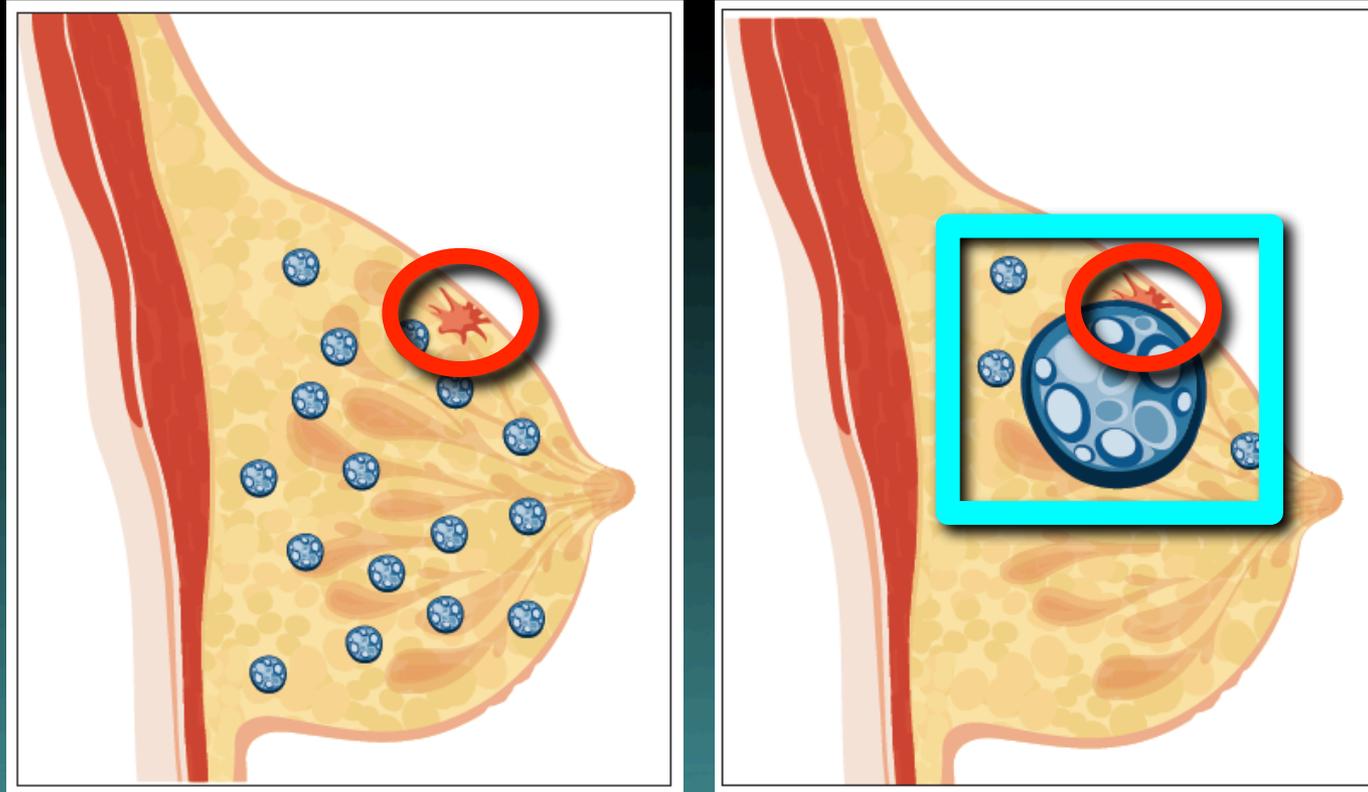


AI APPLICATIONS IN BREAST IMAGING

AI can measure actual **DISPERSION** of dense breast tissue, not just **volume**!



AI APPLICATIONS IN BREAST IMAGING



Same **volume** of glandular tissue, but
different **dispersions-**

**DIFFERENT BREAST CANCER RISK, &
DIFFERENT BREAST CANCER DETECTION!**





SUMMARY OF AI APPLICATIONS IN BREAST IMAGING

- CAD
- FIRST READ OF SCREENING MAMMOGRAMS
- SYNTHETIC 2D MAMMOGRAPHY
- BREAST DENSITY CATEGORIZATION FOR BREAST CANCER RISK
- MUCH, MUCH MORE: Device optimization analytics, positioning & motion algorithms, “smart” machines for further analyses, etc.

AI IS OUR FUTURE!



**THE FUTURE LOOKS BRIGHT AND
INTERESTING FOR BREAST IMAGING!**

**IT IS A PRIVILEGE & A PLEASURE
TO BE PART OF IT, AS WE
CONTINUE SKYWARD!**



Thank you!

MammoMike@aol.com

DR. MICHAEL N. LINVER INTERNATIONALLY RECOGNIZED PHYSICIAN AND EDUCATOR