# Advancements in Mammography and Breast Imaging

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# Objectives

1. Review breast cancer statistics and the current mammography screening guidelines
2. Explore previous technological advances in mammography which have enabled us to detect breast cancer at earlier stages with greater precision
3. Review traditional computer aided detection in mammography and contrast that with the newer artificial intelligence based mammography tools
4. Explore some of the potential ways that AI based mammography models can help us perform better for the women we serve, as well as make us aware of some of the potential pitfalls with this new technology

HEALTH

# Will AI replace doctors who read X-rays, or just make them better than ever?

Ask Me Anything

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WS

Will AI replace radiologists?

AI is unlikely to **completely** replace radiologists, but it will **significantly change their role.**

### Here's why AI won't fully replace radiologists:

1. **Human Oversight is Critical** – AI can analyze images quickly, but it still makes errors, especially in rare or complex cases. A radiologist is needed to verify AI findings and make final diagnoses.
2. **Clinical Decision-Making** – Radiologists do more than just read images; they consult with doctors, recommend treatments, and consider patient history, something AI struggles with.
3. **Liability & Ethical Concerns** – AI cannot be held legally responsible for mistakes, so human oversight will always be required.
4. **AI Limitations** – Even the best AI models can struggle with unusual or low-quality images, requiring human expertise.

### Here's how **AI will change** radiology:

1. **Faster Diagnoses** – AI can analyze scans in seconds, helping radiologists work more efficiently.
2. **Better Accuracy** – AI can detect subtle abnormalities that a human might miss, leading to earlier diagnoses.
3. **Workload Reduction** – AI can handle routine cases, allowing radiologists to focus on complex cases and patient care.
4. **Screening & Triage** – AI can prioritize urgent cases, ensuring critical patients get faster treatment.

### Bottom Line:

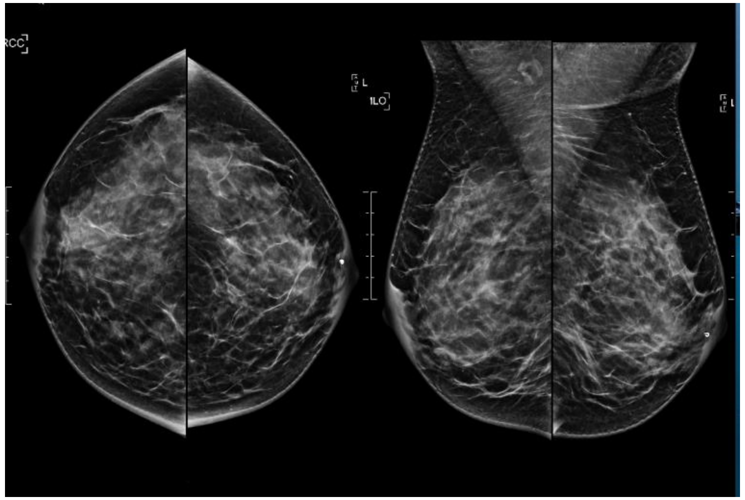
AI will **augment** rather than **replace** radiologists. The future is likely to be a **human-AI collaboration**, where AI handles the repetitive tasks, and radiologists provide the final judgment and patient interaction.

# Breast Cancer

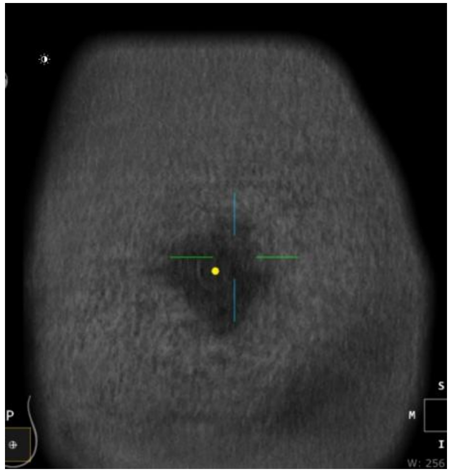
- 1 in 8 women are diagnosed with a breast cancer in their lifetime
- $2^{nd}$ leading cause of cancer death among U.S. women
- In 2023, 43,170 women died of breast cancer (JAMA USPTF 2024)
- Breast cancer death rates have been decreasing
- More than half of cases happen in women without known major risk factors

# Disparities in Breast Cancer

- Non-Hispanic white women and non-Hispanic black women now have similar incidence of breast cancer, but the latter have the highest mortality rate
  - Despite similar self reported rates of mammography
- Reasons that have been suggested include
  - Access to mammography
  - **Health care delivery** (what happens after detection)
  - **Tumor biology** (higher rate of triple negative breast cancer among black women)

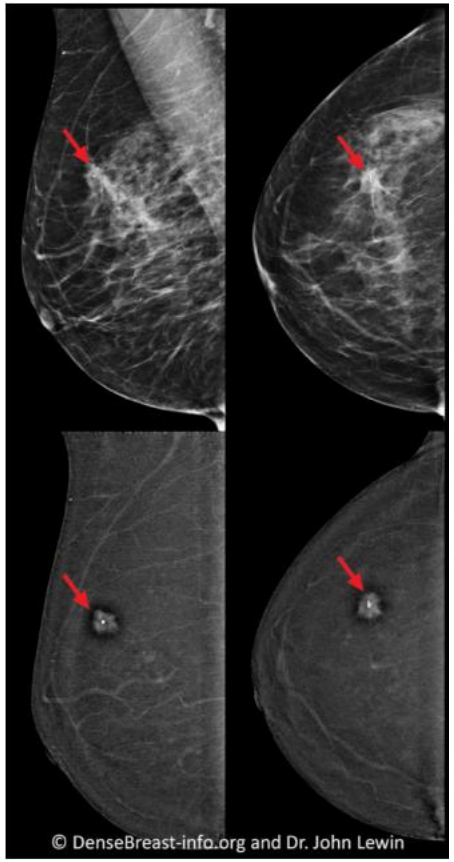


Mammography

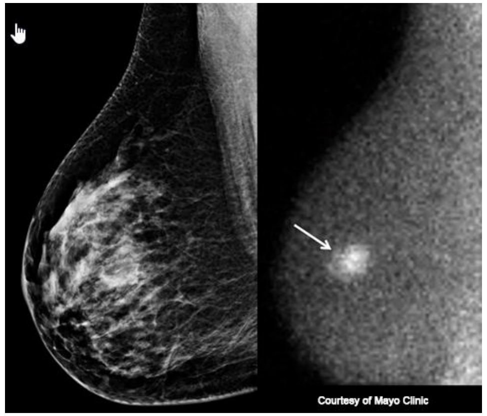


Whole breast ultrasound screening

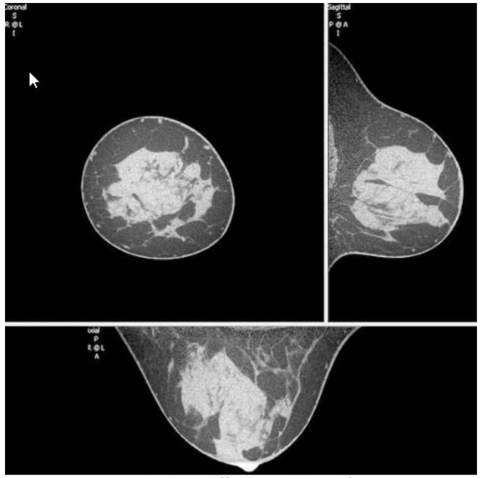
Breast MRI




Contrast enhanced mammography

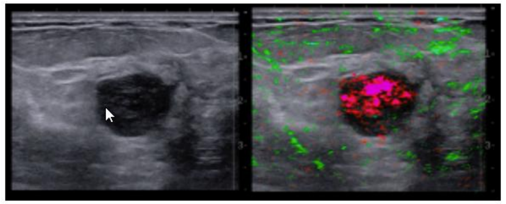



Molecular breast imaging



Source: https://health.ucdavis.edu/

Breast CT



Optoacoustic/ultrasound imaging

# Mammography Screening in the U.S.

- Between 20-40% breast cancer mortality reduction

- In 2021, 75.9% of women ages 50 – 74 self reported that they had a mammogram within the past 2 years (National Cancer Institute, https://progressreport.cancer.gov/detection/breast_cancer)

- In 2022, 59.1% of women ages 40-49 and 76.5% ages 50-74 had a mammogram within the past 2 years
  - Mammography use varied by state and sociodemographic characteristics
  - Lower prevalence of mammography use was associated with factors related to health care access (low income, lack of health insurance, lack of a PCP)
    - Miller JW, King JA, Trivers KF, et al. *Vital Signs*: Mammography Use and Association with Social Determinants of Health and Health-Related Social Needs Among Women — United States, 2022. MMWR Morb Mortal Wkly Rep 2024;73:351-357. DOI: http://dx.doi.org/10.15585/mmwr.mm7315e1

# Current **Average Risk** Screening Guidelines*

| | Age to Begin Mammography | Age to Stop Mammography | Mammography Interval |
|---|---|---|---|
| ACR/SBI | 40 | No age limit, tailor to individual health status | Annual |
| ACS | 45 (optional to start at 40) | Life expectancy < 10 yrs | Annual 45-54; every 1 or 2 years 55+ |
| ACOG | 40 | Age 75, then shared decision making | Every 1 or 2 years |
| AMA | 40 | | Annual |
| ASBrS | 40 | Life expectancy <10 yrs | Annual |
| NCCN | 40 | Age 75, then shared decision making | Annual |
| USPSTF** | 40 | Age 74 | Every 2 years |

*Women at higher than average risk need consideration for earlier and/or more intensive screening

**USPTF recs were amended in 2023, previously recommending individual decision b/t 40 and 50, and all women start at 50

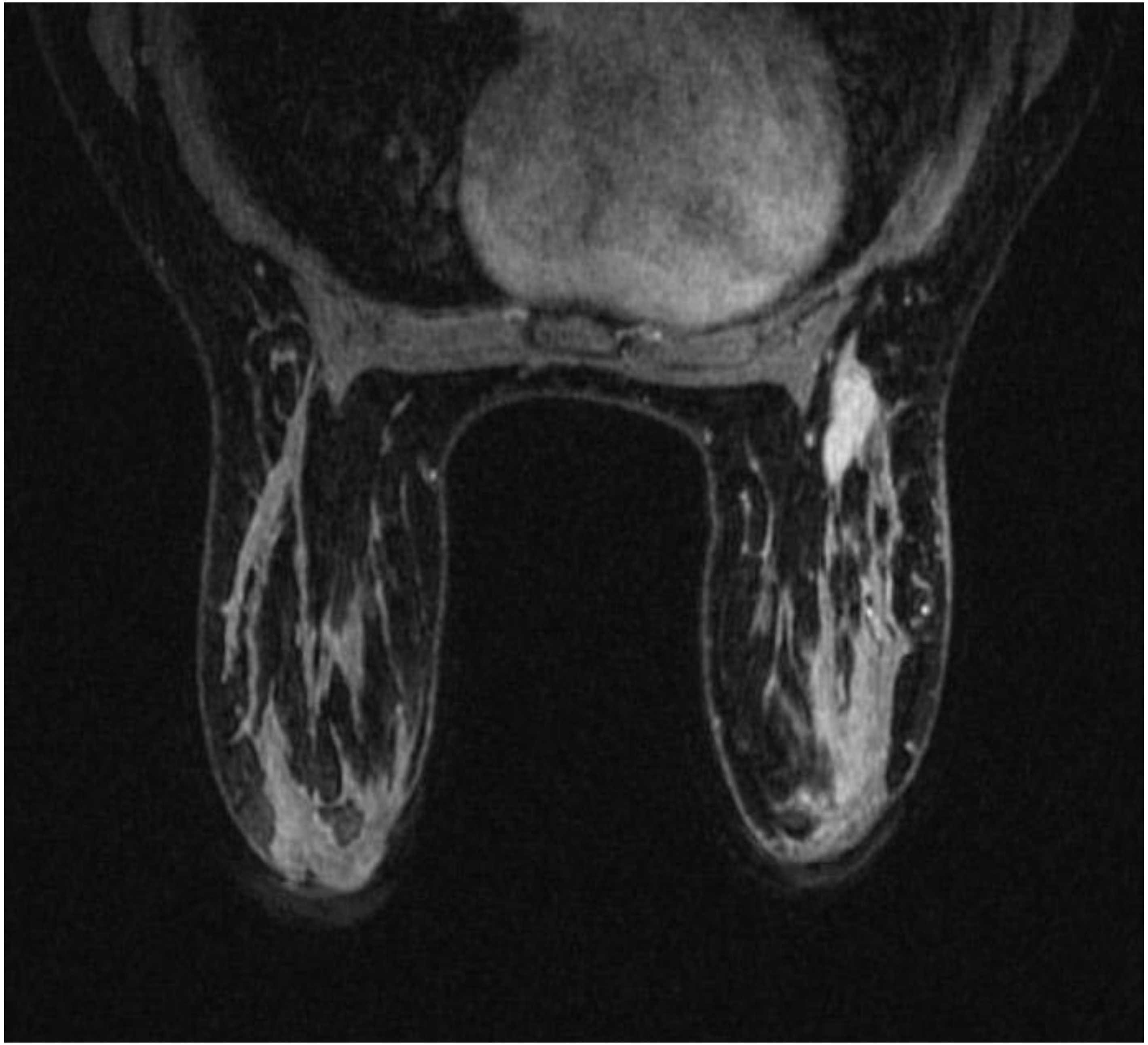
# ACR/SBI **High Risk** Screening Recommendations 2023

- There is mounting evidence that black women, Ashkenazi Jewish women, and other minority groups develop and die from breast cancer prior to age 50 (and even prior to age 40) more often that non-Hispanic white women.
- All women should undergo a breast cancer risk assessment by age 25, especially black women and Ashkenazi Jewish women who are at higher risk for genetic mutations, and for black and other minority women, who are at higher risk of breast cancer at younger ages.
- This allows for planning of appropriate supplemental screening.

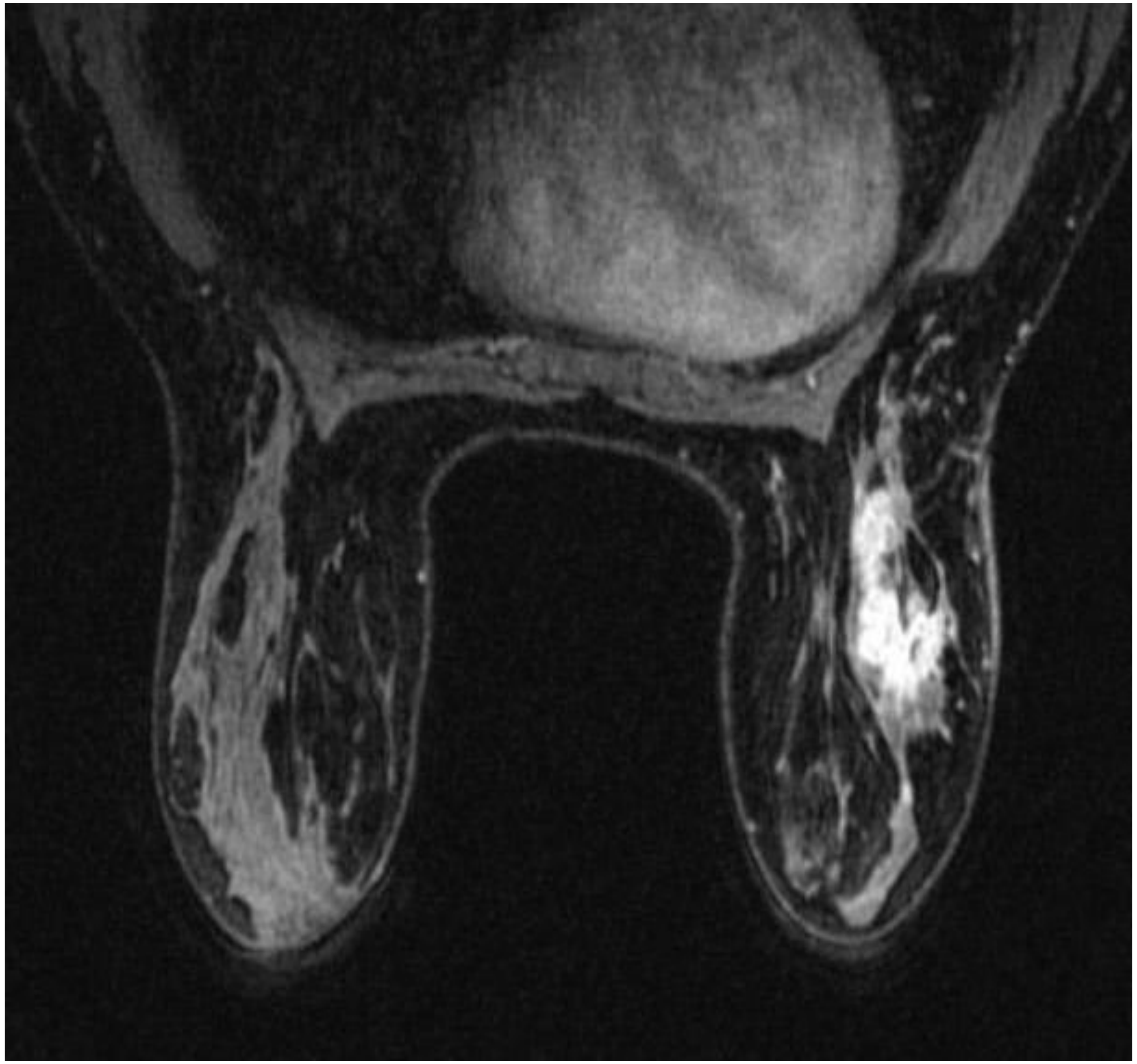
# Patient 1: Jenny, a missed opportunity

- 30 year old woman
- Ashkenazi Jewish heritage
- Mother diagnosed with breast cancer at age 45
- Aunt diagnosed with breast cancer at age 48
- Mother recently diagnosed with BRCA2 gene mutation

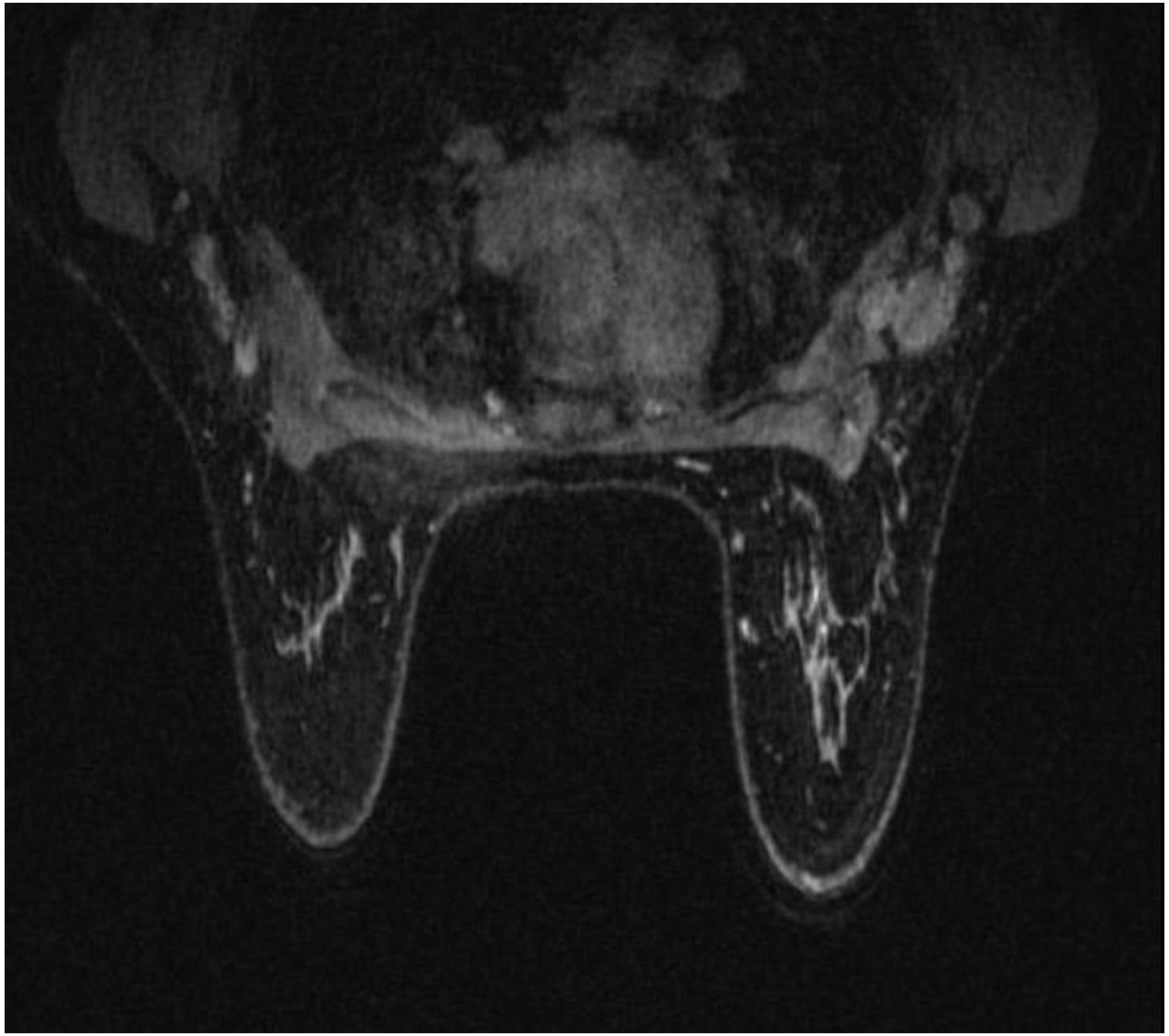
- Jenny is tested and has the BRCA2 mutation
- Jenny undergoes mammography and ultrasound examinations which show masses in the left breast and left armpit
- Biopsy shows invasive cancer with metastatic disease in the left armpit lymph nodes
- MRI subsequently performed



# Breast MRI-**Multifocal Disease** Left Breast



# Axillary Adenopathy



- Jenny was given chemotherapy and underwent bilateral mastectomy (both breasts removed)
- She passed away from breast cancer 2 years later

# THE MAMMOGRAM

PAST AND PRESENT

# What is a Mammogram ?

- an X-ray of the breast
- Requires compression to allow low energy x-rays to penetrate the soft tissue
- Standard screening mammogram has 4 views (CC and MLO view of each breast)
- Mammography remains the best primary tool for breast cancer screening
  - Low cost
  - Widely available
  - Fast

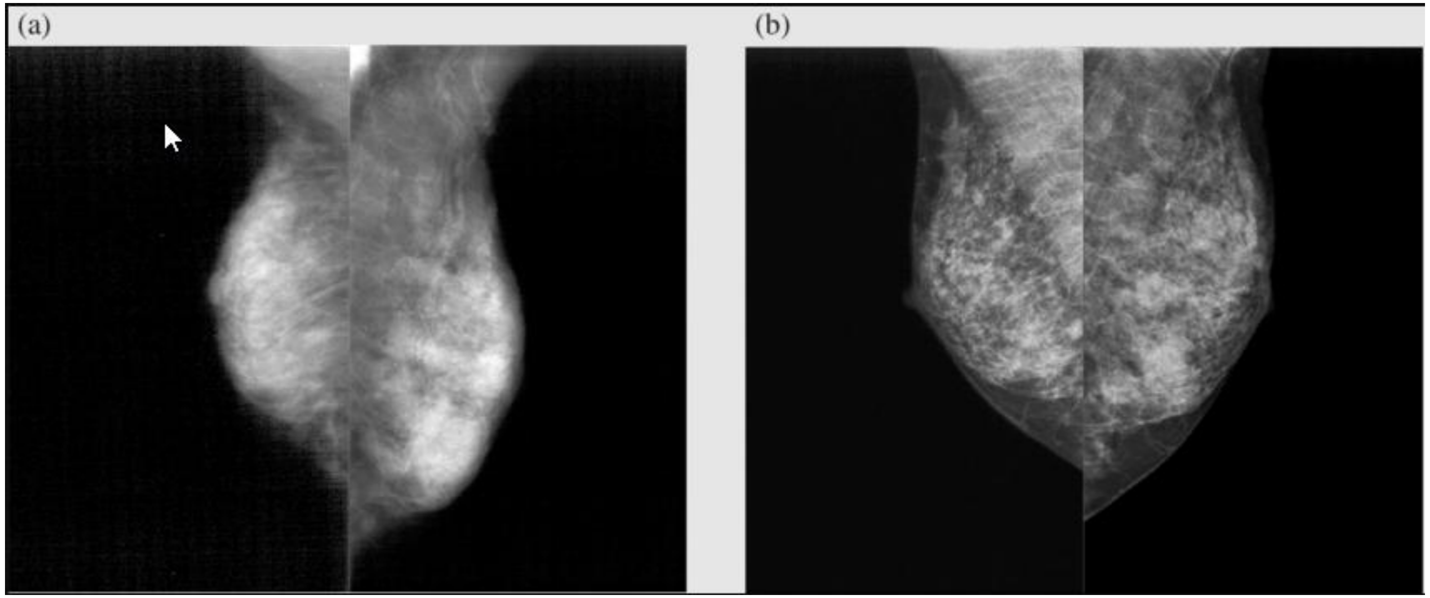
# Screen Film Mammography

- 1913: surgeon Albert Salomon began doing x-rays of excised breast tissue specimens
- 1927: 1st known x-ray of the breast of a living patient was published by German surgeon Otto Kleinschmidt
- 1930: 1st mammogram in the United States performed by radiologist Stafford Warren
- 1965: first dedicated mammography unit was developed by Charles Gros in Strasbourg, France
- Late 1960s: mammography started to spread as a possible screening tool for breast cancer that was not yet clinically palpable

# Digital mammography

- Approved by the FDA in 2000
- Higher diagnostic accuracy, especially for women < 50 and dense breast tissue
- Lower radiation dose (~50% dose reduction)
- Faster image processing
- The x-ray images are stored on computers

THEN




NOW

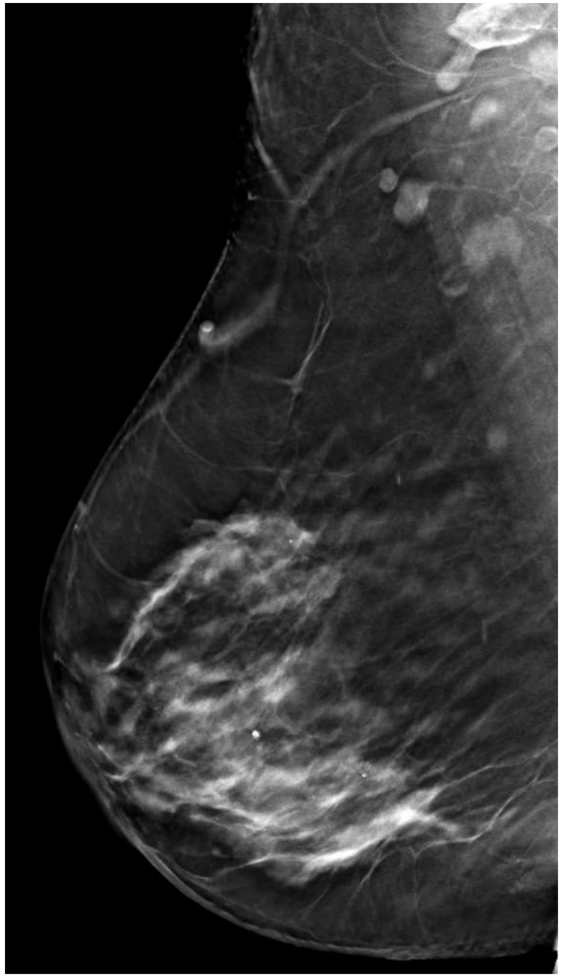
# *Development of the 3D Mammogram*

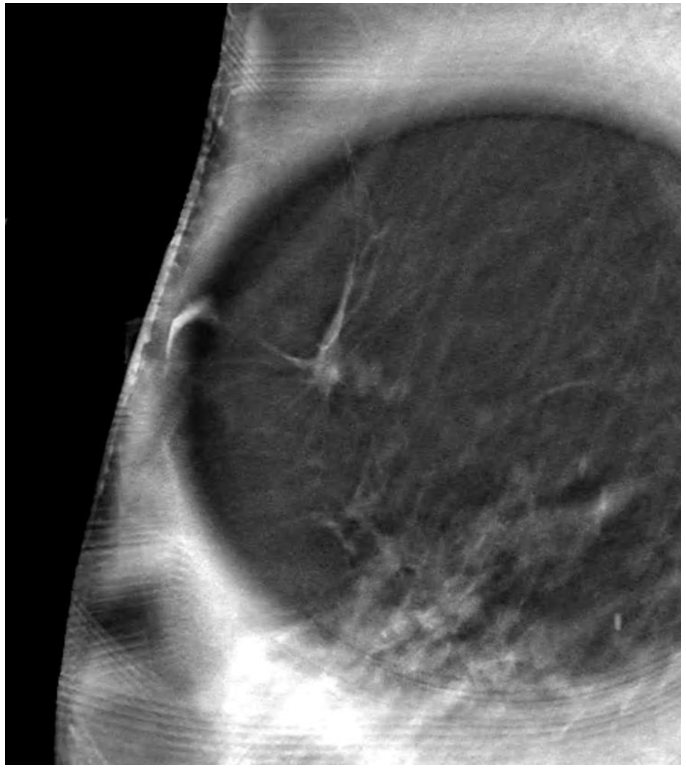
- Multiple projections through the breast to create sectional images of the breast, to overcome issues with tissue overlap
- Improve visibility of masses and architectural distortion

- Increases cancer detection rate
- Reduces false positives

- FDA approval for clinical use in 2011
- Now found in 87% of FDA certified mammography facilities in the U.S.

# Patient 4: 69 y/o female, annual screening, tomo detected abnormality



# Patient 4: 69 y/o female, annual screening, tomo detected abnormality

- 4 mm invasive ductal carcinoma, grade 1
- Lymph node negative
- Patient underwent breast conservation therapy

# Federal regulation

- 1992 Mammography Quality Standards Act (MQSA)
- MQSA Reauthorization Act of 1998
- 2023 MQSA Final Rule

- Why?

To ensure all people have access to quality mammography for the detection of breast cancer in its earliest, most treatable stages

Facilities must document compliance with MQSA regulations to perform mammography in the U.S., and yearly inspections overseen by the FDA are required

# Mammography Audit Performance Measures

- ***Sensitivity*** = TP/TP +FN (TP/total # exams associated with cancer)
  - The probability that a patient with a positive test has breast cancer
- ***Specificity*** = TN/TN + FP (TN/total # exams without cancer)
  - The probability that a patient with a negative result does not have breast cancer
- ***Cancer Detection Rate***
  - # cancers/1000 screening exams
- ***Abnormal Interpretation (Recall) Rate***
  - # BIRADS 0/all screening exams
- ***PPV1***
  - TP/TP + FP (# cancers / all recalls)
- ***False Negative Rate***
  - *FN/1000 screening exams*

SPin – a test with a high specificity (SP) that, when positive, helps to rule in a disease

SNout – a test with a high sensitivity (SN) that, when negative, helps to rule a disease out

# Benchmarks: BCSC update 2018

- Evaluated digital mammography exams performed in U.S. community practices between 2007 and 2013
- Majority of radiologists surpass CDR recommendations for screening mammography, however recall rates are higher than the recommended rate for almost half of radiologists reading screening mammograms.
  - Only 59% of rads achieved recommend recall rate, and 63% achieved recommended specificity level

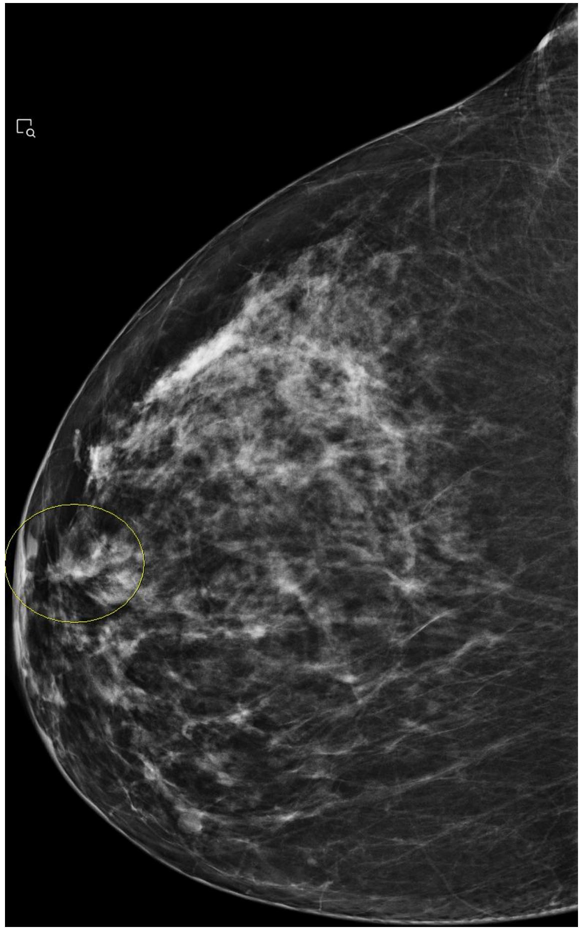
| | AIR (recall rate) (%) | PPV1 (%) | Sensitivity (%) | Specificity (%) | CDR |
|---|---|---|---|---|---|
| **BCSC Update 2017** | 11.6 | 4.4 | 86.9 | 88.9 | 5.1 |

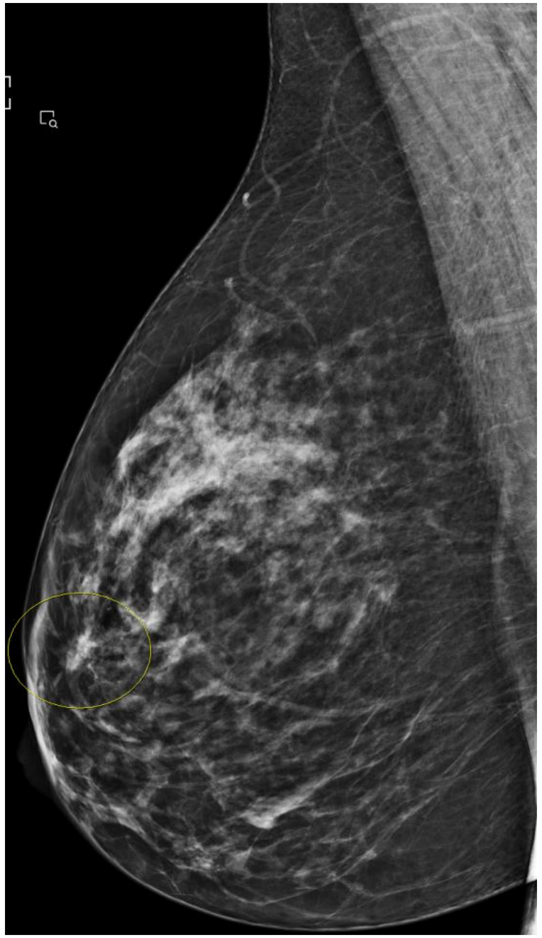
National Performance Benchmarks for Modern Screening Digital Mammography: Update from The Breast Cancer Surveillance Consortium. Lehman et al. *Radiology* 2017.

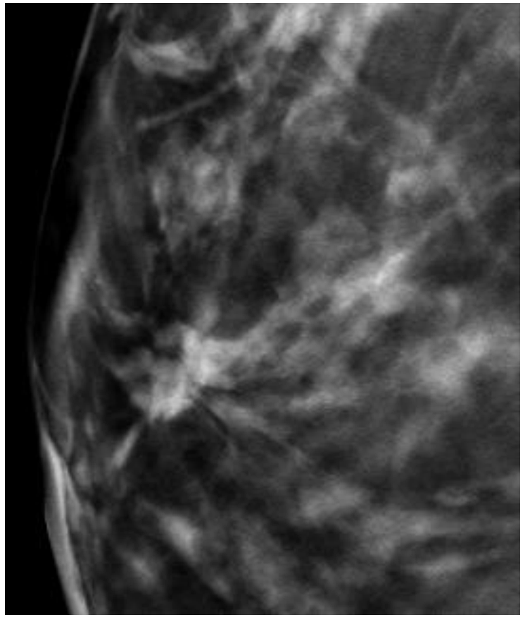
# BCSC Performance Measures for Mammography Examinations from 2011-2018

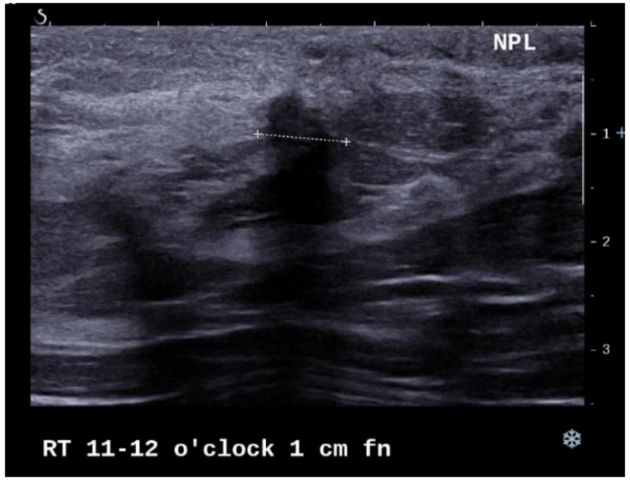
| | AIR (recall rate) (%) | PPV1 (%) | Sensitivity (%) | Specificity (%) | CDR/1000 | FNR |
|---|---|---|---|---|---|---|
| **Digital Breast Tomosynthesis** | 8.3 | 6.9 | 87.4 | 92.2 | 5.8 | 0.8 |
| **Digital Mammography** | 10.3 | 5.2 | 87.6 | 90.2 | 5.3 | 0.8 |

# Patient 2: 42 y/o woman fam hx: maternal gm age 60







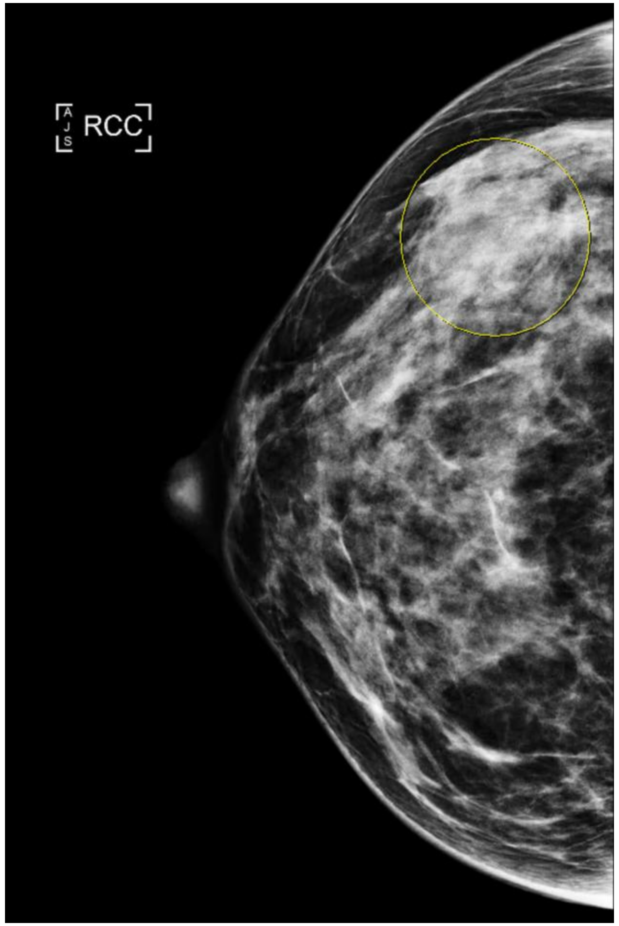


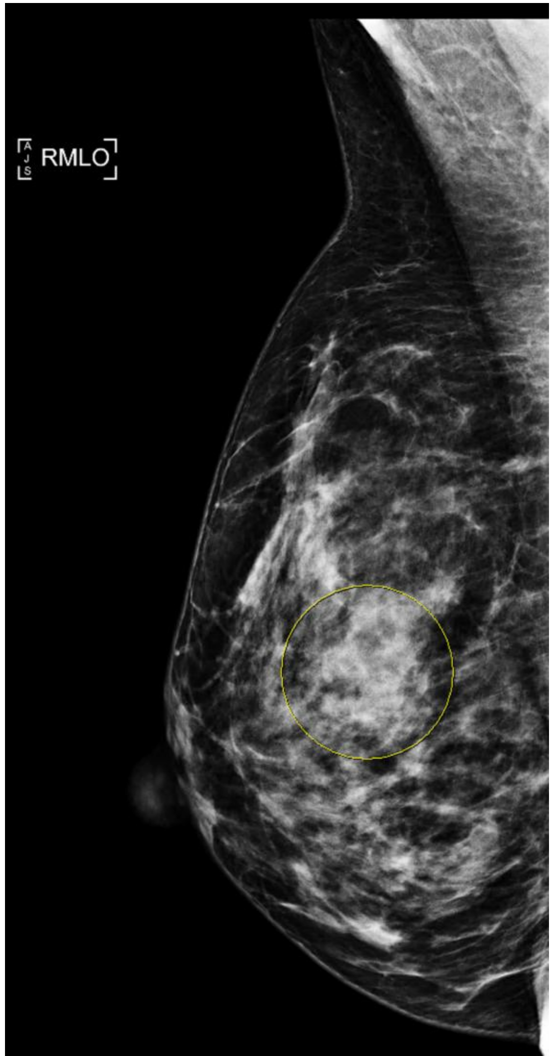
# Patient 2: 42 y/o woman

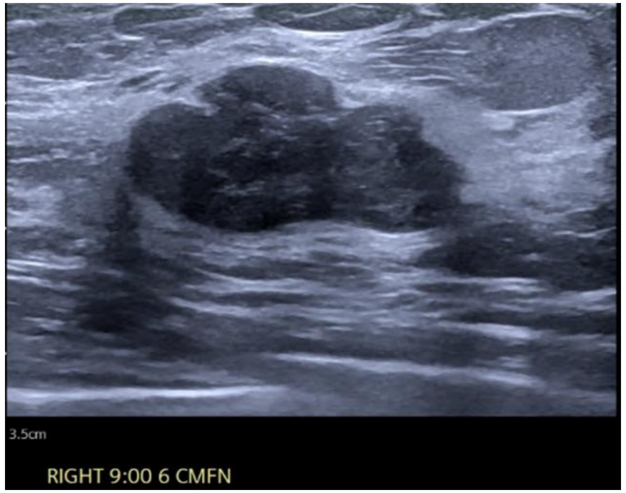
- Invasive ductal carcinoma with lobular features, grade 2
- Clinical Stage IA (TNM: cT1c, cNO, cM0)
- Patient underwent breast conservation therapy and tamoxifen therapy x 5 years, no e/o recurrence

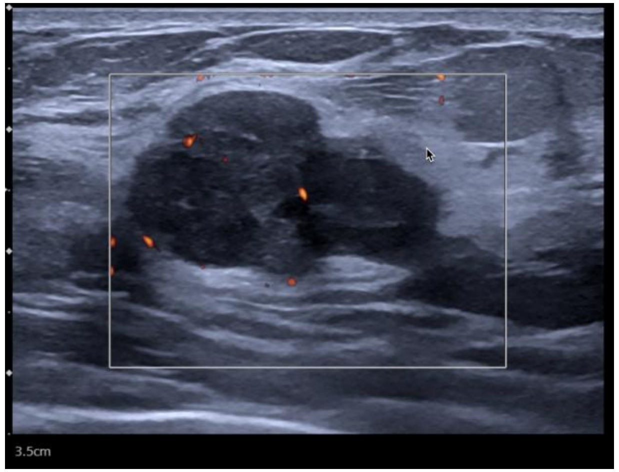
<u>TRUE POSITIVE</u>

# Patient 3: 40 y/o woman, baseline screening mammogram, no fam hx



# Patient 3: 40 y/o woman, baseline screening mammogram

- Diagnosis: fibroadenoma, no evidence of atypia or malignancy
- Recommended to return to annual screening mammography

<u>FALSE POSITIVE</u>

# Criticisms – potential 'harms' of mammography

- False positive result
  - Anxiety
  - Cost
- False negative result
  - 'missed' cancer
- Overdiagnosis
  - Detection of a cancer that would not become clinically relevant
- Radiation exposure

Over 50% of patients undergoing 10 screening mammograms will have a false positive callback and 10% will have a benign biopsy

False positives cost approximately $2.8 billion annually in the U.S.

False positives may also reduce future screening compliance

# Double Reading

- Two radiologists read a mammogram
- Increases cancer detection and decreases false negative rate, and may be used to reduce recall rates  (reduce false positives)
- Studies have shown that double reading increases the cancer detection rate by 5% to 15%
- Not widely used in clinical practice in the U.S., due to the increased cost, time and interference with practice workflow
- Still face the human factors (fatigue, distraction, etc)

# MAN AND MACHINE

Computer aided detection in mammography

# Computer Aided Detection (CAD)

- 1960s – earliest concepts of using computers to automatically detect mammographic abnormalities
- 1980s – systematic development of machine learning techniques for medical imaging began
- 1998 – FDA approves 1st commercial CAD system
- 2002 – CMS approves reimbursement of CAD after which it becomes widely disseminated (overlap with conversion to FFDM & PACS)
- 2008 – CAD was used in 74% of screening mammograms
- 2016 – CAD was used in 92% of screening mammograms

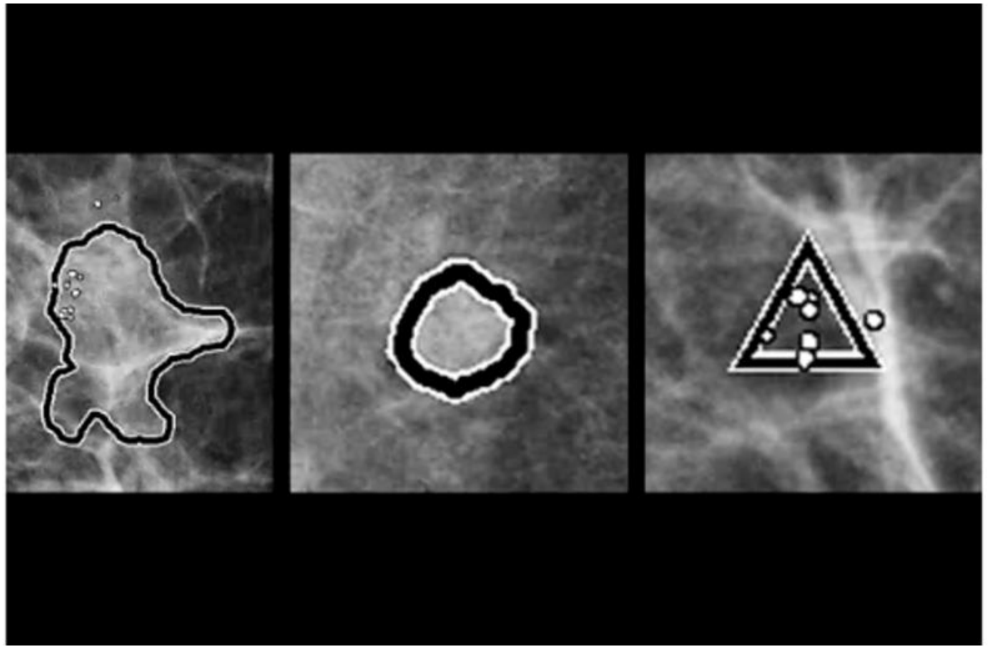
# Traditional Computer Aided Detection

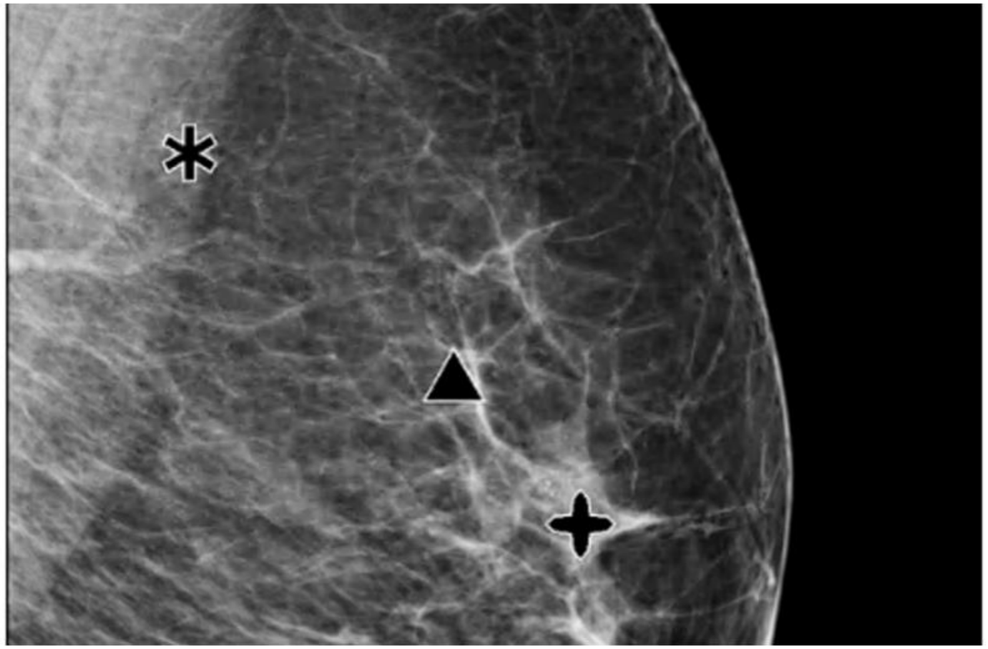
- Designed to be a second opinion to assist the radiologist
- Flags calcifications, masses, asymmetries, and architectural distortion
- Typically the radiologist will read the mammogram first, and then review the CAD marks
- Increases sensitivity
  - But, not all cancers are picked up by CAD
- CAD marks have low specificity (increases false positives!)
  - CAD will mark numerous normal findings that the radiologist will then dismiss
- Outcome depends on the opinion of the interpreting radiologist
- Cancers may be overlooked if CAD fails to mark a suspicious lesion

# Traditional CAD in the Real World

- Despite early promise, large community-based studies could not reproduce benefits of CAD software seen in early trials
- 2007 study
  - 429,345 mammograms
  - No significant change in CDR or Sensitivity
  - Statistically significant decrease in Specificity (increase in biopsy rate)
- 2015 BCSC
  - >600,000 mammograms, 271 rads
  - No improvement in screening performance with CAD
    - Cancer detection rate, sensitivity and specificity all unchanged
  - CAD preferentially increased detection of DCIS (calcifications) and did not alter detection of invasive cancers (masses and distortions)
- Double reading has still been found to be better than single reader with CAD

# CAD markings





# New Frontiers in CAD: Deep Learning

# Artificial Intelligence

The ability of a machine to imitate intelligent human behavior

## Machine Learning

a subfield of artificial intelligence

### Deep Learning

produces data with multiple levels of abstraction

# Deep Learning

- Relies on artificial neural networks, such as CNNs (convolutional neural networks) used in mammography AI
- Many layers within the network allow for more complex pattern recognition
- CNN-based CAD programs learn from data over time and improve their performance
- AI systems for breast cancer screening show promise in improving diagnostic performance

# Traditional CAD Vs. Deep Learning Based CAD

**Traditional CAD**

- Slower CPUs and limited storage
- Manual features (based on human input)
- No feedback or learning

**Future Deep Learning Based CAD**

- Faster computers and large storage
- Deep neural networks
- Continuous feedback and learning→ ability to improve

# AI Cancer Detection

Input large data set of annotated images (manually annotated by radiologists, typically expert readers)

CNN model is trained using the prepared dataset

AI system analyzes the images for masses, distortion, calcifications, and asymmetry

Localizes, segments, and classifies lesions

Lesion score and Exam score

# MASAI Trial

- Landmark RCT in Sweden
- AI supported screening to triage exams to single or double reading
  - AI system gave exams a malignancy risk score of 1 – 10
  - For exams deemed intermediate (8-9) and high risk (10), the AI system also marked suspicious findings and gave a regional risk score of malignancy on the mammogram
  - Low and intermediate risk exams underwent single reading, and high risk underwent double reading
- Detection of 29% more cancers <u>without</u> increasing false positives
- 44% reduction in screen reading workload
- Are the increased cancers being detected clinically relevant?
  - The increased detection was mostly of small, node negative, invasive cancers
  - Not increased detection of low grade in situ cancers

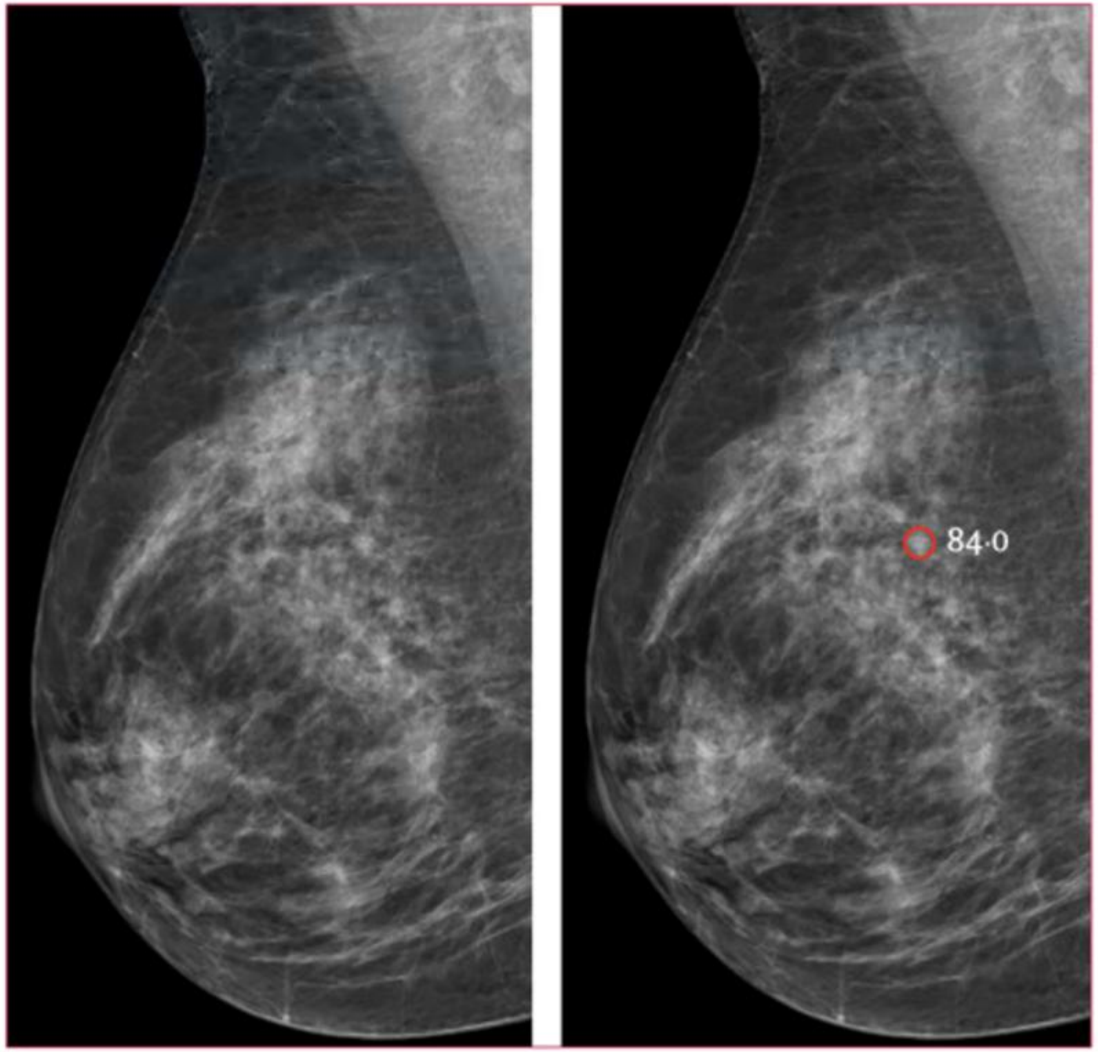



Figure 1 Mediolateral oblique mammographic view of a screening examination with risk score 10

5 mm invasive ductal carcinoma,
node negative

https://www.thelancet.com/journals/landig/article/PIIS2589-7500(24)00267-X/fulltext

# AI Triage of Screening Mammograms

- Most screening mammograms are normal
- AI triage system used to help identify and de-prioritize negative mammograms
- Radiologist focuses energy on abnormal or potentially abnormal mammograms
- Can reduce radiologist workload and prioritize reading of (potentially) abnormal exams

# AI Picking up False Negatives

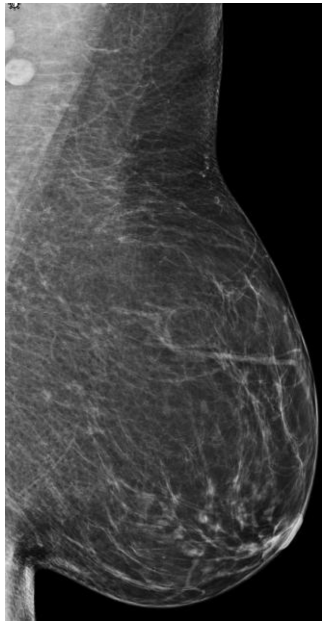
- False negative – cancer diagnosed within 1 year of a negative screening exam (includes cancers detected on another imaging modality)
- Retrospective review applied a commercially available AI system to 26,694 FFDM and 3,183 DBT exams (non-enriched real world population)
- AI algorithm identified 54% of false negative cancers in the FFDM group, and 40% of false negative cancers in the DBT group (location specific analysis, meaning the AI tool marked the correct location)
  - The false negative cancers were all invasive and were predominantly luminal A subtype. Majority had minimal signs on the preceding screening MG.
- AI improved CDR, but the role of the radiologist was not replaced
  - 50% of FFDM and 20% of DBT flagged studies had a high AI score but wrong location
  - 6 % of screen detected cancers in FFDM group and 4% in DBT group (identified by the radiologist) were missed by the AI algorithm
- Potential for earlier detection of false negative cancers with aid of AI tool, than by radiologist alone

# Breast Cancer Risk Determinants

- Personal and family history
- Genetics
- **Breast density**
  - Can hide breast cancer on mammogram, and slightly increases the risk of breast cancer

# Automated Breast Density Assessment with AI

- Objective, reliable and consistent breast density assessment
- Dense breasts have higher risk
- May lead to recommendation for supplemental dense breast screening



# Breast Cancer Risk Determinants

- Personal and family history
- Genetics
- Breast density
  - Can hide breast cancer on mammogram, and slightly increases the risk of breast cancer
- **Mammographic Parenchymal Pattern** – image based risk assessment
  - AI analyzes the complexity of the mammogram, and provides a personalized short-term 1-2 year risk of developing cancer after a normal mammogram (Profound Risk, iCAD) -- No morphologically identifiable lesion
  - May perform better than traditional risk models (Gail Model, Tyrer Cuzick model)

# Potential Concerns About AI in Breast Imaging

- Could AI widen existing disparities or create additional barriers ?
- Increased cost
  - $40 - $100 per exam, out-of-pocket
- Limited availability (eg small or resource poor institutions)
- Lack of standardization & regulation
- Patient privacy and data security
- Bias, if built with datasets that don’t represent the real world population being served
- Responsibility and liability

# Thank you! Questions?

the breast center

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