Mammography

Thursday June 5th

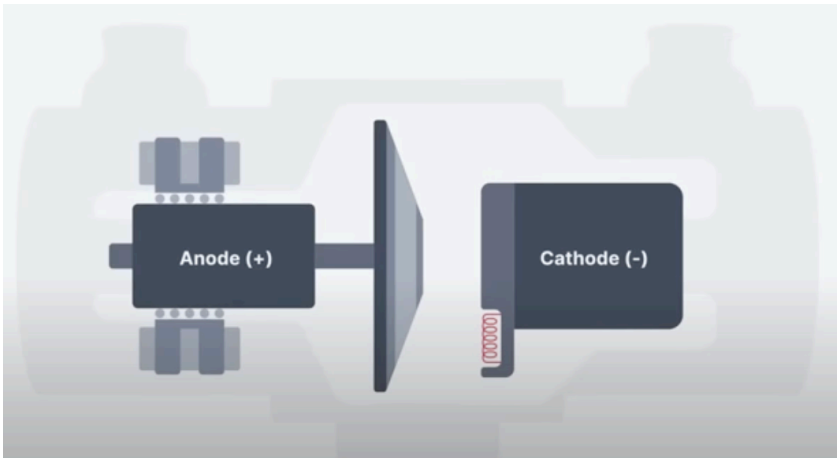
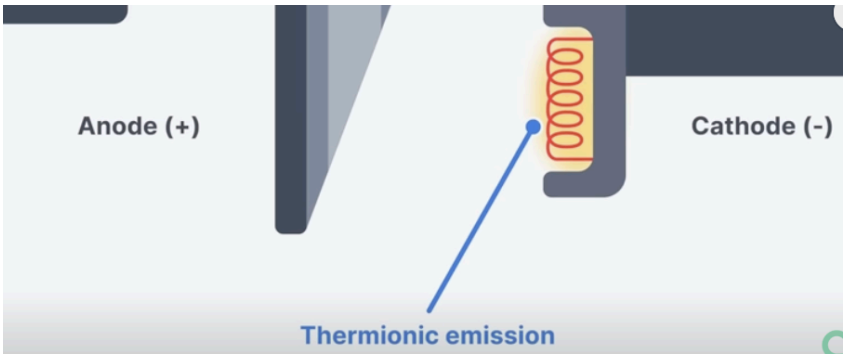
Source: https://pmc.ncbi.nlm.nih.gov/articles/PMC10252579/

History, when it started, timeline?

- Pathology: study of taking body tissue, and examining it to understand the cause and effect of diseases
- X-rays were first discovered in 1895 by Rontgen in Germany (mammography is a low-dose X-ray imaging specified for the breast tissue)(it uses low energy to enhance contrast and resolution of softer tissues)
- The first mammogram was performed in 1913 by German surgeon Albert Soloman, in his paper "*Contributions to the Pathology in Clinical Medicine of Breast Cancer*", which shows the different types of breast cancer and how they spread through the axillary lymph nodes (the lymphatic system defend against foreign particle - carry white blood cells)
    - The test was done on 3000 mastectomies (breast tissues)
    - Tests were done on excised specimens
- WW1 happened, and research stopped
- In 1927 (Paper: "*The Clinic of Malignant Tumors*"), German surgeon Otto K, and Erwin P published the first known radiograph of the breast tissue from a living patient (using X-ray imaging)
- In 1930, Stafford Warren performed the first mammogram in the USA, and showed how it could be a useful tool before the surgical operation. He also mentioned that examination of both breasts was required to allow better identification of abnormalities
- In the late 30s, radiologist Gershon-Cohen and pathologist Helen Ingleby analyzed the abnormalities from the birth of the breast and its normal variation according to age, menstrual status, pregnancy, and lactation, as the knowledge of what is normal is a prerequisite to understanding what is pathological
    - They also analyzed malignancies
- In 1951, a radiologist from Uruguay focused on microcalcifications (Microcalcifications are tiny deposits of calcium salts that are too small to be felt but can be detected by imaging. They can be scattered throughout the mammary gland or occur in clusters. Microcalcifications can be an early sign of breast cancer. Based on morphology, it is possible to classify by radiography how likely microcalcifications are to indicate cancer. Microcalcifications in the breast are made up of calcium phosphate or calcium oxalate), to distinguish between benign and malignant
    - Developed breast compression technique to improve image quality and decrease radiation
    - Identified 30–50% of non-palpable (non-noticable) breast cancers
- In the late 1960s, mammography started to spread as a possible screening tool

What is an X-ray? How are they made?

- NOTE: X-rays are not safe because their radiation can cause broken cells at the atomic level, which could repair to form mutations
- For X-rays to be formed, we need excess (or a source of) electrons, the means of accelerating or ionizing those electrons, and a means of decelerating and de-energizing those electrons.
- In a x-ray tube, thermionic emission (which is the release of electrons in response to heat) (very high current flows, that when metal gets hot enough, electrons are emitted, and form an electron cloud around the cathode), happens at the cathode (negative terminal)
- Next, an electric voltage is applied to accelerate these electrons, which forces electrons across the X-ray tube to the positively charged anode
- Now, the process of accelerated electrons crashing into the anode makes the electrons release their energy as heat
- Therefore, increasing tube current and voltage increases the number of photons (particles representing a quantum of light or other electromagnetic radiation) (higher voltage produces higher beam quality)

- 
Anode (+)
Cathode (-)
(x-ray tube)
- 
Anode (+)
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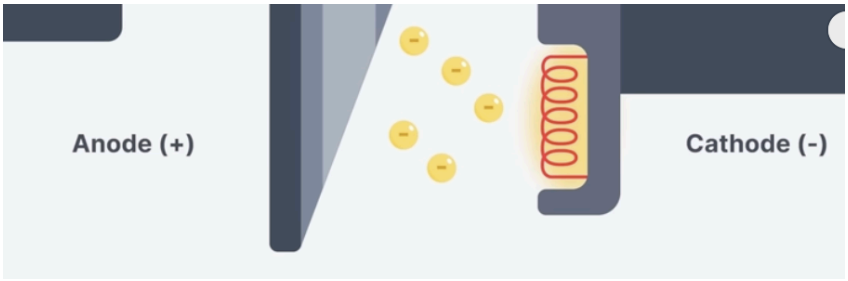
Thermionic emission
- 
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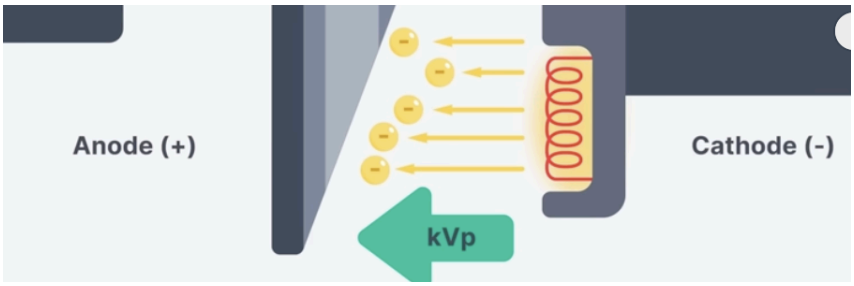
- 
Anode (+)
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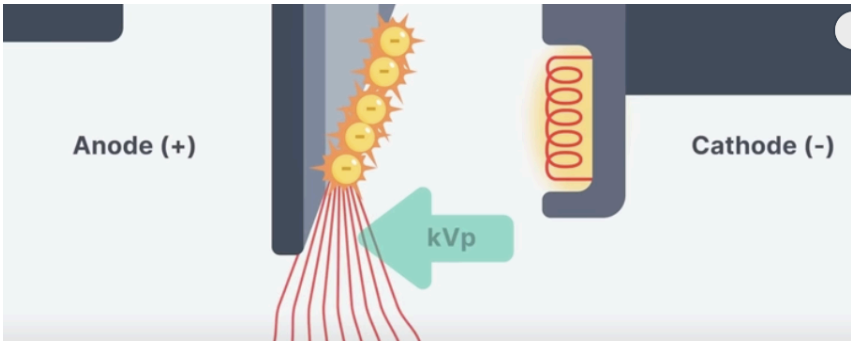
kVp
- 
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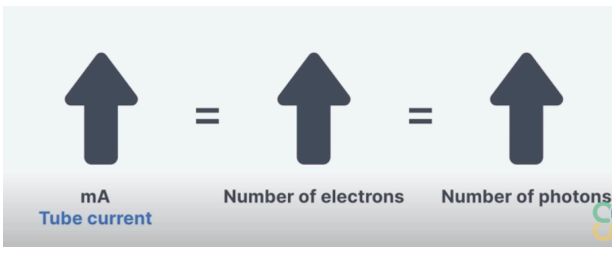
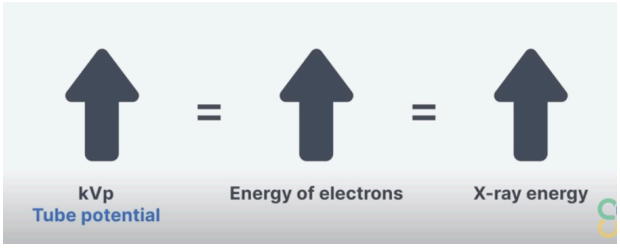
- 
=
=
mA
Tube current
Number of electrons
Number of photons

- 

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(exposure time - time current is running and voltage being applied)
- How are X-ray images produced? X-rays leaving the X-ray tube pass through the body, and then different tissues absorb different amounts of the X-rays (for instance, bone, denser tissues, and less dense tissues absorb different amounts of X-rays). Then the remaining X-rays leaving the body are seen at a detector, which converts the intensity of transmitted X-rays into a grayscale image
-

Tissue Type	Atomic Number (Z)	Density	X-ray Absorption
Bone	High	High	Strong (white)
Muscle	Medium	Medium	Moderate (gray)
Fat	Low	Low	Less (darker gray)
Air (lungs)	Very low	Very low	Minimal (black)

What different X-ray techs were involved

What are radiologists?
- Doctors who specialize in diagnosing and treating conditions and injuries using imaging equipment

What tools do radiologists use to analyze X-ray mammography images?
- Xeroradiography (imaging such that the image appears on paper rather than film) was used as an alternative to X-rays
    - Provides better image detail and a lower dose of exposure
- In the late 1960s, Charles Gros developed the first X-ray designed exclusively for mammograms using a molybdenum tube instead of a tungsten tube (previously, X-rays were used in units intended for other diagnostic procedures, such as chest X-rays)
- Moving grid for mammography was introduced in 1978, which reduces the scattered radiation and further improves imaging
- Digital mammography in 2000, in digital mammography, the transmitted radiation is transferred to an electric image detector instead of on film
- Recently, in digital mammography, X-rays are captured by an electronic detector instead of film. This allows image acquisition and storage to be separated, enabling better efficiency. The main goal is to maximize image information while minimizing radiation dose. Technological advances have shifted the focus from image storage to absorbing X-rays efficiently and producing high-quality images, with the detector converting absorbed energy into a signal that is transformed into an image
- Digital Breast Tomosynthesis (DBT) - when tissue overlaps, resulting in difficulty in detection. Here multiple X-rays are projected from different angles. Made in the early 1990s
- CEM
    - An iodinated contrast agent is injected into the patient's bloodstream (helps enhance visibility of the tumor)
    - Contrast circulates bloodstream and accumulates more around the tumors. WHY?
        - Increased vascularity (more blood vessels), which causes higher concentration in iodine

    - Dual-energy subtraction highlights area where iodine is concentrated (subtracts low-energy of normal mammogram (which is just breast tissue) from high-energy (iodine-enhanced area))
- MRI - strong magnetic field put on the body forcing the hydrogen protons (found in water, fat, tumors) to align with the field. Then a RF pulse is sent to the body , temporarily knocking out the protons. Depending on how the protons align (they emit radio signals) the computer can process to form images.
    - Contrast between tissues is how fast protons relax
    - Images are formed using K-space (storing the spatial frequency data) and using 2D or 3D fast fourier transforms to convert k-space into a real image
- Ultrasound - sounds waves, transducer

Be as exhaustive as possible when looking into the tools that radiologists
what tools they are interested in to get these images
How AI could be used in mammography
CT system
Reach out to Hamid
Time harmonic is non causal

Thursday June 12th

GPT Deep research:https://chatgpt.com/c/68489d2b-e3f8-800b-a2b4-187df48e9679

Early detection in MIT: https://seeflection.com/18087/mit-develops-breast-cancer-early-detection-tool/

MIT and cs team:
https://news.mit.edu/2019/using-ai-predict-breast-cancer-and-personalize-care-0507#:~:text=With%20that%20in%20mind%2C%20a,are%20precursors%20to%20malignant%20tumors

Major Manufacturers
https://lbnmedical.com/guide-to-mammography-systems/#:~:text=The%20major%20players%20on%20the,Fuji%2C%20Hologic%2C%20GE%2C%20and%20Siemens

- Hologic
- GE Healthcare
- Siemens Healthineers
- Fujifilm

Conventional Mammography
- Image capture done by capturing x-rays on photographic film which is then stored physically on film
    - Photographic film refers to a physical sheet coated with photosensitive chemicals (chemicals that react to x-rays)
- Here the image is fixed (no post capture manipulation, like zoom, brightness,...)
- Less effective in dense tissues

CT system: https://www.nibib.nih.gov/science-education/science-topics/computed-tomography-ct
- Narrow beam of x-rays are aimed at a patient and quickly rotated around the body
- Machines computer generates cross-sectional (slices: thickness ranges from 1-10mm) images from produced signals by x-ray detectors across of human
- These cross-sectional images are called tomographic images
- Successive slices are digitally stacked together to form 3D image of patient
- Conventional X-ray uses a x-ray tube, CT system uses a motorized x-ray source
- Just like in x-ray it is difficult to scan softer tissues but easier to detect bones, we use contrast agents to detect items in a CT scan. For example, to examine the circulatory system, an intravenous (IV) contrast agent based on iodine is injected into the bloodstream to help illuminate blood vessels

Tools Radiologists use in Mammography

- Full field digital mammography (FFDM)
    - Captures X-rays using digital detectors (digital detector are placed behind the human, when x-ray hits it, it creates a digital image)
        - Digital detectors can either process light, or the electrical signal directly (in both cases an ADC is used to form digital image)
            - Direct a-Se flat panels convert X-rays to charge for very sharp images
            - CsI-based detectors use a scintillator crystal with needle-like structures to guide light and minimize blur
- Digital breast tomosynthesis (DBT):
    - Acquires multiple projections images spanning from 15 - 50 degrees and reconstruct into stack of ~1mm slice
    - Similar to CT system but just for the breast tissue
        - Difference between CT:
            - Just does breast tissue
            - Only does 15-50 degrees while CT does 360 degrees
            - Lower radiation dose
            - Less number of projections required to create 3D image
- CEM
    - dual-energy X-rays (uses 2 x-rays: low and high energy) are used to differentiate between normal tissue and areas with iodine contrast uptake. The low energy image shows anatomy, while the high energy image highlights iodine. When subtracted, they create an image that isolates the iodine concentrated areas (faster and at a lower cost compared to MRI).
- Technical specifications
    - 20 - 40 kV peak is maximum voltage applied across the x-ray tube, we tend to use lower kVp because lower energy x-rays are more readily absorbed by soft tissue, creating better image contrast, but still high enough to penetrate the breast quickly
    - The target (which is the part inside the x-ray tube that the electrons hit) are made molybdenum, rhodium, tungsten because they produce lower energy x-rays (typically around 17-23 keV)
    - The filter
        - Thin piece of metal (also molybdenum, rhodium, tungsten) placed in x-ray beam after it leaves the target
        - Removes unwanted x-rays by:
            - Removing low energy (that would not make it past the skin)
            - Removes high energy (that would reduce contrast)
        - Purpose of the filter is to minimize the energy spectrum for the x-ray

Interpretation Tools

- Picture Archiving and Communication Systems (PACS)
    - Review MRI, Ultrasound, FFDM in same session
    - Current and past images
    - Left and right image comparisons
- Displays are recommended to be 5 megapixel (2048 × 2560 pixels) grayscale monitor
- Use computer aided detection (CAD) software to mark areas that algorithmically appear off
    - Problem: false positive/negative results
    - assess margin sharpness or calcification patterns to suggest malignancy vs benignity
    - Some focus on detection and prompting
- breast density assessment tools -these tools help radiologists by providing consistent density estimates that can be included in reports and used to identify women who might benefit from supplemental screening

AI in Mammography

PROBLEM: RADIOLOGIST DO NOT TRUST THE AI

- AI does advanced pattern recognition from training off of thousands of mammograms
- Applied for risk predictions: analyzing a woman's mammogram to predict her future risk of developing breast cancer
- Integrated into workflow for ease
    - AI results (marks, scores, or triage decisions) should be readily available on the same workstation or PACS that the radiologist uses,
- AI models like *Mirai* or *Clairity* can produce a 5-year cancer risk score from a normal mammogram
    - Current models use age, family history, or self-reported questionnaires
    - Clairity uses the mammogram itself
- Triage model
    - Goes through mammograms deciding which are normal vs suspicious
- Most imaging centers worldwide have not yet integrated AI into routine mammography practice, because of the need for more evidence of outcome improvements, costs of systems, integration challenges, and radiologists' trust.
    - AI is being used for more after the radiologist to verify
- Mammography Screening with Artificial Intelligence trial (MASAI) study
- Korea's national screening program

Training
Thesis??
Google scholar
What do they train their techniques on

CNN basics

HOW LONG DOES IT TAKE A BREAST TISSUE TO GROW??? HOW LONG DOES IT TAKE A MUTATION TO GROW???

Categories of breast density

🔷 Category A: Almost Entirely Fatty

- **Description**: The breast is composed of **mostly fat** with very little fibroglandular (dense) tissue.
- **Imaging**: Appears **dark** on mammograms (fat is radiolucent), making abnormalities easy to see.
- **Cancer Risk**: **Lowest** among the four categories.
- **Prevalence**: Common in older women or postmenopausal individuals.

🔷 Category B: Scattered Areas of Fibroglandular Density

- **Description**: There are **scattered areas of dense tissue**, but the majority of the breast is still fatty.
- **Imaging**: Mildly mixed density; most lesions can still be seen.
- **Cancer Risk**: Slightly increased compared to Category A.

🔷 Category C: Heterogeneously Dense

- **Description**: The breast has **many areas of dense tissue**, which can **obscure small masses**.
- **Imaging**: Dense tissue appears **white**, similar to tumors, reducing visibility.
- **Cancer Risk**: **Moderately increased**.
- **Prevalence**: Very common, especially in women under 50.

🔷 Category D: Extremely Dense

- **Description**: The breast is composed of **mostly dense tissue**, with very little fat.
- **Imaging**: Appears very **white** on mammograms, making tumor detection very difficult.
- **Cancer Risk**: **High** — about **4–6 times higher** risk than in women with fatty breasts.
- **Prevalence**: More common in **younger women**, premenopausal women, or those with certain hormonal influences.

MIT Work (model is pattern recognized trained on millions of pixels)
- MIT's computer science and artificial intelligence laboratory (CSAIL) and massachusetts general hospital (MGH)
- Trained on 90,000 mammograms with known 5 year outcomes

- Model predicts from mammogram if patient is likely to develop breast cancer as much as 5 years in the future, rather than using traditional risk models (which rely on factors like age, family history, and coarse breast density categories)
- Model learned subtle patterns in breast tissue that are precursors to malignant tumors
- These patterns essentially capture the unique breast tissue characteristics of each patient, which reflect underlying influences such as genetics, hormonal and reproductive history, prior pregnancies or lactation, weight changes
- CNN's intermediate layers will extract features like subtle variations in tissue density distribution, fine textures, masses or calcification patterns too minor to flag as lesions, and other imaging biomarkers that correlate with eventual cancer development
- prioritizes features that have prognostic relevance rather than human designed risk factors
- may rely on different fine-grain tissue patterns and relative orientations of those patterns depending on global patterns in a patient's breast, and they are distinguishing patterns for women with dense/less dense tissues
- PATTERNS
    - Fine textures and Parenchymal Patterns
        - The CNN looks into the overall parenchyma (background tissue) pattern at the granular level.
        - Detects subtle texture variations in the fibroglandular tissue that may indicate elevated risk.
        - They look into spatial arrangement of tissue intensities beyond the dense vs fatty argument
        - Captures complex textures (heterogeneity or fine grain in the stroma)
    - Density distribution and gradients
        - Some of the traditional metrics that radiologist use is breast density, BI-RADS system, and non imaging clinical risk factors (such as age, family history, personal history)
        - However, It may pick up local density gradients or regional density pockets that signal risk. For example, rather than just a percentage of density, the model could recognize if dense tissue is clustered in certain quadrants or if there is a stark asymmetry in density between regions of the breast
    - Minor calcifications and subtle lesions (lesion is any damage or abnormal change in the tissue of an organism, usually caused by injury or diseases)
        - Not just for breast tissue but more generically
    - Global parenchymal symmetry vs asymmetry https://www.rsna.org/news/2024/march/deep-learning-for-predicting-breast-cancer#:~:text=%E2%80%9CPreviously%2C%20differences%20between%20the%20left,%E2%80%9D
        - Comparison between left and right breast
        - Asymmetry between tissue density or texture is a biological marker
        - Developed AsymMirai model that compares difference between left and right breast using saliency maps
- Comparisons to traditional markers
    - Breast density: radiologists classify into four densities. AI factors in how density is distributed and other texture cues
    - Traditional risk model are shown disadvantageous toward african american women because (see bullet points) therefore this AI model trained by diverse dataset removes this bias
        - Traditional models were developed from white population
        - African women are more likely to have dense breast which is harder to detect cancer
- What the Saliency maps showed
    - Key findings:
        - **Focus on meaningful regions**: The model often highlights **fibroglandular tissue**, especially areas with **dense texture or asymmetry**, rather than irrelevant or random regions.
        - **Localized attention**: In some cases, saliency maps show the model focuses on **specific breast regions** where cancer later develops—even if radiologists initially saw no signs there. This suggests it detects **early subtle changes** or **pre-cancerous cues**.
        - **Bilateral comparison**: A simplified model (AsymMirai) confirmed that **differences between left and right breasts** are highly predictive. The model learns to flag **localized asymmetries in tissue patterns** as key risk indicators.
        - **Diffuse vs. focal patterns**: Rather than single hot spots, risk saliency is often **spread across regions**, reflecting the **distributed nature of risk** (e.g., global texture or density distribution).
        - **Clinically aligned attention**: Saliency maps generally align with **clinically relevant features**, like dense regions or subtle abnormalities, supporting trust in the model's reasoning.
    -

Tyrer-Cuzick Model

- Relies heavily on manually reported or measured risk factors
  - Age
  - Family history
  - Personal history of breast conditions
  - Hormonal and reproductive history
  - Breast density
  - Genetic mutations

Mirai is trained on millions of pixels rather than creating predictions on measured risk factors. It looks into fine textures and details (so looking into small variations in the fibroglandular tissue), look

🔍 Side-by-Side Comparison

Feature	Tyrer-Cuzick Model	MIT AI Model (Mirai)
Type	Statistical risk model	Deep learning (CNN)
Input data	Patient history + family + density	Mammogram images (raw pixel data)
Uses breast image?	Partially (via density)	✅ Fully uses mammographic image
Handles racial variation well?	❌ No	✅ Yes (trained across races)
Customizes to individual	✅ Based on risk factors	✅ Based on patient's imaging biomarkers
Interpretability	✅ Transparent factors	❌ Black-box
Clinical integration	✅ Widely used	⚠️ Early adoption stage
Predictive accuracy	Moderate (AUC ~0.62–0.65)	Higher (AUC ~0.68–0.76 depending on dataset)
Requires genetic data?	Optional but supports it	❌ Not needed

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Look more into calcifications, how we can use low freq to detect calcifications
Find urls
Download processing software

Thursday June 26th

GPT deep research: https://chatgpt.com/c/685afe9a-4e20-800b-9c1d-0c4218eb66c8

- models, including Gail, BCSC, Rosner–Colditz, and Tyrer–Cuzick, have been developed to predict breast cancer risk
- Microwave imaging of malignant/benign tissues propounds as an alternative methodology to detect cancerous tissues and it is capable to penetrate up to ample depths beneath the skin tissues, depending upon the tissue compositions [2]. It investigates the dielectric contrast in between the healthy and malignant tissues.

Articles that look in calcifications
- https://radiopaedia.org/articles/breast-calcifications - different types of calcifications
    - coarse heterogeneous: irregular, generally 0.5-1 mm
    - amorphous: indistinct and/or small ("powdery", "cloud", or "cottony"), such that another specific shape cannot be determined
    - fine pleomorphic: variable shape ("shards of glass" or "crushed stone"), generally <0.5 mm
    - fine linear or fine-linear branching: thin (<0.5 mm), linear, branching or irregularly arranged ("casting")
- https://www.mdpi.com/2379-139X/9/1/10 - professor emilio from university of padova uses ML algorithm to detect lesions
    - Use higher frequencies from 1-9GHz
- K. C. Lai, P. J. Slanetz, R. L. Eisenberg, Linear breast calcifications, Amer- ican Journal of Roentgenology 199 (2) (2012) W151–W157.
    - https://ajronline.org/doi/10.2214/AJR.11.7153
    - Types of calcifications to look for
        - Linear options: Vascular, sutural, secretory
- https://arxiv.org/pdf/1904.09870 - early detection using near field microwave holography

Doable?
- However using low frequency antennas provides good penetration the wavelength of a smaller frequency increase (f = 1/lambda)
- Usually microcalcifications are 0.3-0.6mm - 200 MHz has a wavelength of 1.5meters

Alternative:
- Look into higher frequencies or UWB (0.5 - 10 GHz)

Potentially look into genomic mutations and how we can use AI to model
https://pmc.ncbi.nlm.nih.gov/articles/PMC10987819/#B33 (look at references 33,34)

WHAT DO I WANT
- Research - done
- Name published on paper
- Lab work

What patterns
Why specifically cant we use low freq to determine micro calcifications

Thursday July 17th

https://chatgpt.com/c/68819db6-41dc-8329-9f69-b730bcd78bff

https://chatgpt.com/c/68819db6-41dc-8329-9f69-b730bcd78bff

https://chatgpt.com/c/687875c0-e86c-800b-826a-3469d136fe32

https://www.nature.com/articles/s41598-023-40494-x#:~:text=limitations,not%20give%20a%20robust%20correlation

https://chatgpt.com/c/685afe9a-4e20-800b-9c1d-0c4218eb66c8

When an EM wave encounters a material with different electrical properties (like permittivity or conductivity) than the surrounding medium, the wave gets altered (part of it reflects, part of it refracts, and part may get absorbed). These changes are collectively called scattering or perturbations of the EM field. So when we work with micro calcifications (0.3mm), it does not perturb the outgoing wave from the antenna enough to detect anything https://aapm.onlinelibrary.wiley.com/doi/full/10.1002/mp.17873 - article that explain how Researchers created realistic synthetic breast phantoms with microcalcifications of varying sizes and contrasts embedded in simulated breast tissue. Detection performance improved with larger calcifications and higher contrast, while smaller or lower-contrast microcalcifications were frequently missed

- Use VIT:
    - the use of virtual platforms, where the human subject is replaced with a digital twin and the imaging system is replaced with a simulated version of the device, provides an alternative approach to evaluate and optimize existing and new imaging technologies
- They place artificial lesions in breast/creating artificial cancer cases
- In patient backgrounds, the correctly detected fraction of microcalcifications clusters fell from 0.53 for the lowest density (VBD < 4.5%) to 0.40 for the highest density (VBD ≥ 15.5%)
- What is AUC:
    - This AUC measures how well observers correctly locate true microcalcification clusters (with credit given for localization) versus making false-positive localizations in images without signal.
    - It's a summary metric: higher AUC = better localization sensitivity at a given acceptable false-positive rates (Mean AUC of ~0.70 for patient images means that on average, readers achieved a 70% performance in search/localization accuracy. Higher AUC values for phantom backgrounds (up to ~0.76) indicate these backgrounds were easier to search—observers made fewer misses or mislocalizations relative to false positives.)
- 4 backgrounds/test environment:
    - One with real images from patients
    - Simulated background images of two digital phantoms, the SSBT phantom
        - The volumetric breast density (VBD) of the SSBT phantoms was 12% ± 4%, calculated from the fraction of voxels identified as glandular tissue relative to the total number of voxels in the 3D voxel model.
    - virtual version of the L1 phantom, were then generated using a virtual imaging framework
        - virtual container with exactly the same number of spheres as in the physical phantom
    - and the physical L1 phantom (which is a test object created)
        - filled with water and equal volumes of PMMA spheres of six different diameters (15.88, 12.70, 9.52, 6.35, 3.18, and 1.58 mm).
- Human observers evaluated detection performance using a Jackknife Alternative Free-Response ROC (JAFROC) metric. They reported:
    - An average AUC of ~0.70 for real patient images,
    - AUC values around 0.74–0.76 for phantom (simulated) images
    - Critically, detection performance decreased in dense/heterogeneous tissue:
        - The fraction of correctly detected microcalcification clusters dropped from **~0.53 in low-density tissue to ~0.40 in high-density tissue**
        - This means more than half of the tiny calcifications were missed, especially in complex backgrounds close to **0.3 mm.**

Linear branching/Articles: (https://chatgpt.com/c/6886bd5d-1a28-8323-bff8-545296281ed9)

- https://www.ajronline.org/doi/10.2214/AJR.09.3423

    - The Positive Predictive Value of BI-RADS Microcalcification Descriptors and Final Assessment Categories (2010)– Bent *et al.*, *AJR Am J Roentgenol*. This retrospective study (146 lesions) assessed malignancy rates for different mammographic microcalcification morphologies in a digital era. It found that fine linear or linear-branching microcalcifications had about a 70% likelihood of malignancy, significantly higher than other calcification typesquantason.com. BI-RADS descriptors were strongly predictive of cancer; fine linear/branching calcifications were most often associated with ductal carcinoma in situ (DCIS) or invasive malignancy, underscoring their high diagnostic significance.
- https://www.academicradiology.org/article/S1076-6332(20)30339-1/abstract
    - Is There Any Association Between Mammographic Features of Microcalcifications and Breast Cancer Subtypes in Ductal Carcinoma In Situ? (2021) – Aslan *et al.*, *Academic Radiology*. This study of 66 patients with pure DCIS examined microcalcification patterns in relation to ER/HER2 status. The authors found a significant correlation between calcification morphology and tumor subtype ($p = 0.026$)pubmed.ncbi.nlm.nih.gov. In particular, fine pleomorphic or fine linear-branching microcalcifications were present in 85% of HER2-positive DCIS cases, versus 71% of ER-positive and only 25% of triple-negative DCISpubmed.ncbi.nlm.nih.gov. Moreover, fine linear-branching calcifications in a linear or segmental distribution were more often associated with comedo necrosis (high-grade DCIS)pubmed.ncbi.nlm.nih.gov. These results indicate that HER2-driven, high-grade DCIS tends to exhibit linear/branching calcifications on imaging, whereas low-grade ER-positive DCIS more often shows less suspicious calcification patterns.