Mammography – Radiation Dose, QA

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Reading Assignment

1. Bushberg et al. The Essential Physics of Medical Imaging, Ch. 8
2. Huda. W., Review of Radiologic Physics, 4th edition, Ch.8
3. AAPM/RSNA Physics Tutorial for Residents:
   http://pubs.rsna.org/doi/pdf/10.1148/rg.246045102
4. ACR Mammography Accreditation Program Requirements:
   http://www.acraccreditation.org/~/media/ACRAccreditation/Documents/Mammography/Requirements

Radiation Exposure/Dose

- Sufficient exposure required for good I.Q. (↓Noise)
- Speed of film/screen system:
  - Fast: Less exposure/Higher Noise Reduced patient dose
  - Slow: More exposure/Less Noise Increased patient dose
- Signal of digital system:
  - Pixel value; index inversely related to exposure
  - Established during calibration - based on exit exposure
- Good contrast requires:
  - Low kVp ➔ ↓Penetration ➔ ↑Entrance dose to breast
  - ↓ Filtration ➔ Low en. X-rays (Low HVL) ➔ ↑Dose
  - Film O.D. high enough (increase mAs):
    Linear high contrast region of H&D curve
  - Grid ➔ Reduced scatter vs. Increase Dose

Dosimetry

- Measurement of radiation dose

- Purpose:
  - Performance of system
  - Evaluate Radiation risk to patient
  - Compare imaging systems and techniques
  - Provide dose info. for physicians, technologists, patients
  - Compliance with regulatory guidelines

Dosimetry

- **Factors Affecting Dose**
  1. Choice of imaging system and technique
  2. Beam quality (HVL)
  3. Compression (breast thickness)
  4. Breast composition
  5. Use of grid
  6. Film - Required optical density
  7. Film processing
  8. Digital: Dynamic range of detector, Calibration of detector

Dosimetry

- **Measurement of radiation dose to breast:**
  - **Special mammography ionization chamber**
  - **Dosimeters: TLD, Semi-conductor metal oxide**

- **Measurement**
  - **Standard mammography phantom (Q.A)**
  - **Thickness: 4.2 cm equivalent**
  - **Composition: 50% adipose 50% glandular**

Dosimetry (MGD)

- **Mean glandular dose (MGD)**
  - **MGD is dose descriptor used in mammography**
  - **Average dose to the glandular breast tissue**
  - **More relevant parameter; primarily glandular tissue at carcinogenic risk**

$$MGD = ESE \times D_gN$$

  - **ESE determined from exposure measurement at phantom entrance**
  - **D_gN: f-factor for mammography (mrad/R or mGy/R)**
  - **determined from tables**
  - **function of kVp, HVL, thickness, composition**

Dosimetry (MGD)

- **Mean glandular dose (MGD)**
  - **Legal requirement:**
  - **With grid MGD for standard phantom:**
    - » **3 mGy (300 mrad) or less per view**
    - » **Represents ‘average’ technique/typical breast**
  - **Typical range:**
    - » **1 - 2 mGy (100 – 200 mrad)/view for**

      4.2 cm compressed breast; 50% adipose/50% glandular

Radiation Dose

- **Dose Reduction**
  - Reduce compression thickness
  - Choice of target/filter combination
    - » Mo/Rh or Rh/Rh vs. Mo/Mo combination
  - Technique: kVp, mAs, auto/AOP modes
  - Calibration: speed of system
    - » Film O.D.
    - » Digital pixel value; index
  - Proper placement of photocell (screen/film)
  - Processor stability (screen/film)
  - Education, Q.C. ➔ Reduce retakes

Radiation Dose

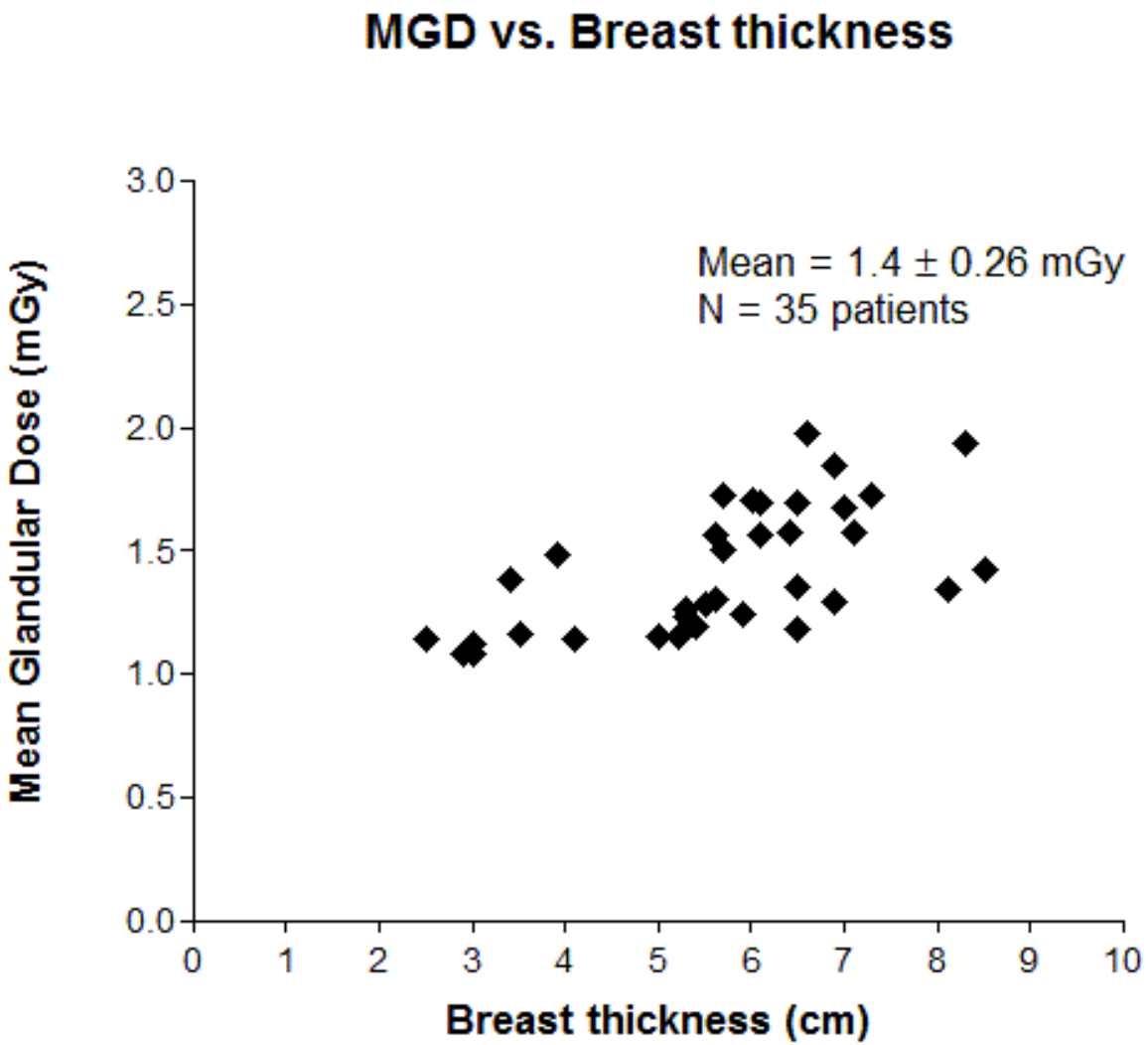
- **MGD: Mean Glandular Dose**
- **Typical MGD: 1.75 mGy (175 mrad)/exposure**

Risk:	Breast Dose (mGy, mrad)	Eff. Dose (mSv, mrem)
PA chest	0.015, 1.5	0.02, 2
Mammography	7, 700	0.80, 80
Chest CT	10.6, 1060	6.8, 680

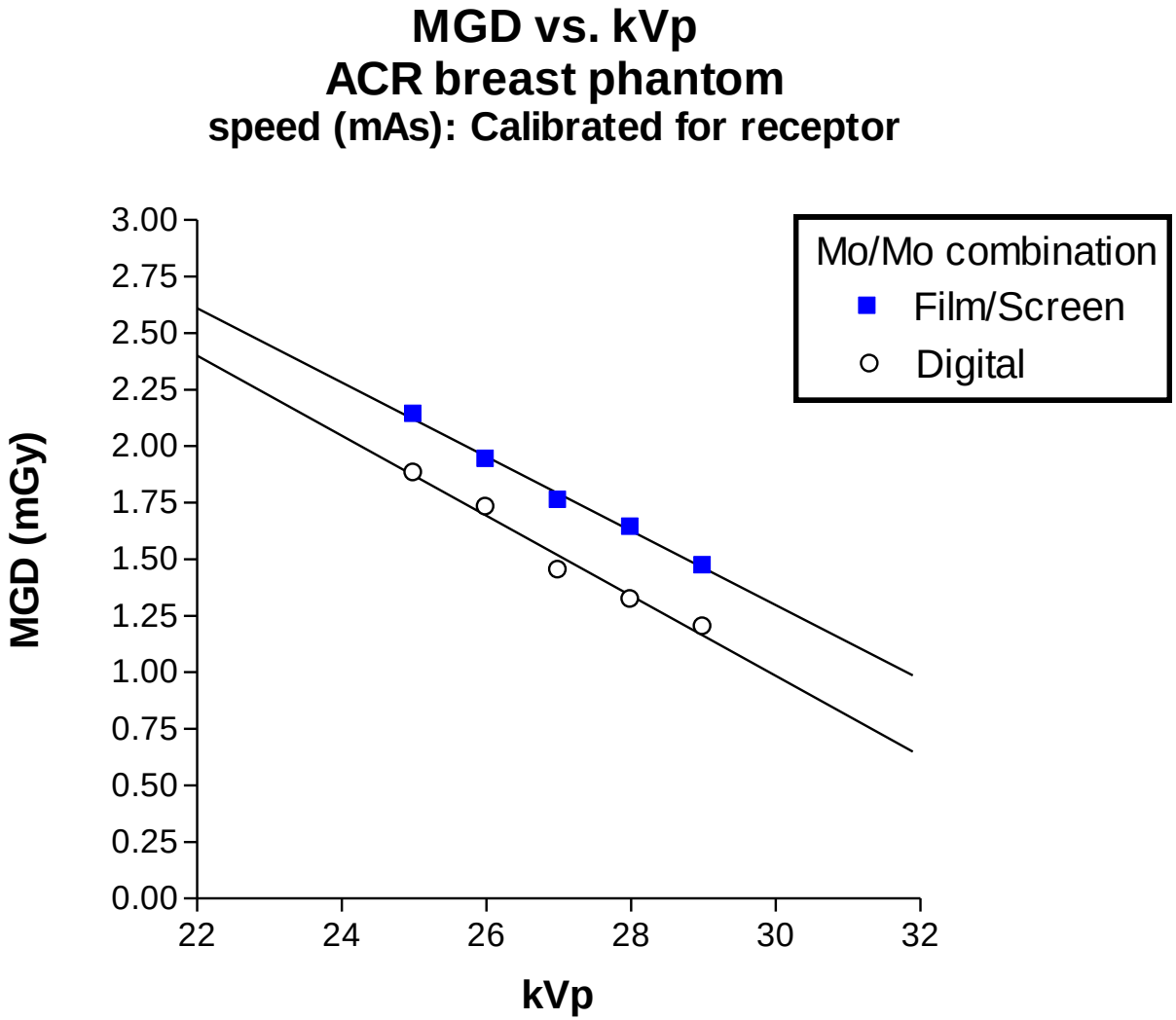
*Annual Background: 3.6 mGy (360 mrad) - whole body

- **Sufficient dose required for good image quality**
  - Noise determined by no. of x-ray photons at receptor
  - Detector determines speed of system and thus dose/noise tradeoff

Radiation Dose



Radiation Dose



Radiation Risk

- **Radiation risk ∝ Radiation dose (MGD)**
  - **Breast tissue at carcinogenic risk; only organ exposed**
- **Risk Models: estimate excess risk**
  - **Additive: no. of excess cases or deaths due to breast cancer**
    - » $\frac{\text{excess cancers}}{10^6 \text{ women-yr-mGy}}$
  - **Relative: % increase in natural breast cancer incidence**
    - » **RR = 1.1 ➔ Excess of 10% above natural**
  - **Somewhat related to age at exposure**

Radiation Risk

- **Ex. Calculation using Risk Coefficient and Effective dose**
  - **Risk = Risk Coeff. x Dose**
  - **Patient exposed at given time**
  - **4 view mammogram:**
    - **MGD = 7 mGy (organ dose)** **tissue weighting factor, $w_T = 0.12$**
    - **Effective dose = 0.8 mSv**
  - **Risk coeff. = (5×10^{-5})/mSv** **Dose = 0.8 mSv**
  - **Risk = 0.004%**
- **Benefits of screening**
  - **Detect earlier stage disease; much improved prognosis**
  - **Reduce mortality with subsequent screenings**

Radiation Risk

- **Radiation Doses and Cancer Risks from Breast Imaging Studies**

  R. Edward Hendrick, PhD, Radiology: Volume 257: Number 1—October 2010

"According to the most recent radiation risk estimates, a single bilateral two-view digital or screen-film mammography examination is associated with a lifetime risk of inducing fatal breast cancer due to radiation exposure of 1.3–1.7 cases in 100,000 women aged 40 years at exposure and of less than one case in one million in women aged 80 years at exposure."

Mammography Quality Assurance (QA)

- **Purpose**
  - Provide consistency of image quality
  - Improved accuracy of diagnostic task
  - Fewer repeat exposures
  - Keep radiation dose to patient adequate
- **Q.A Program**
  - Comply with performance specifications and regulations
  - Maintain proper functioning of equipment
  - Educate personnel: technologist, physicist, radiologist
  - Radiation protection

Q.A. Standards

U.S. Department of **Health & Human Services**

U.S. Food and Drug Administration

Mammography Quality Standards Act (MQSA) and Program

- Became law,1992
- Accreditation and certification
- Maintenance of certification
- Minimum quality standards for:
  - Personnel
  - Equipment
  - Quality Assurance
  - Radiation dose
  - Medical audits, recordkeeping, reporting

Quality Assurance

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QUALITY IS OUR IMAGE

Mammography

- **Accreditation: Initialization of QA**
  - **Mammography facility:** **Overall program, personnel**
  - **Equipment:** **Mammography Units**
  - **Performance:** **Pass/Fail, Corrective Action**

- **Continuous QA**
  - **ACR Monitor performance:** **1, 3 year intervals**

QA Tests – Technologist

Film/Screen

1. Darkroom cleanliness (Daily)
2. Processor QC (Daily)
3. Screen Cleaning (Weekly)
4. Phantom Image Quality (Weekly)
5. Viewbox/Viewing conditions (Weekly)
6. Visual Checklist (Monthly)
7. Repeat Analysis (Quarterly)
8. Analysis/Fixer Retention (Quarterly)
9. Darkroom Fog (Semi-annual)
10. Film/Screen contact (Semi-annual)
11. Compression force (Semi-annual)

Digital

1. Monitor Cleaning (Daily)
2. Flat Field Test (Weekly)
3. Phantom Image Quality (Weekly)
4. CNR/MTF Measurement (Weekly)
5. Viewbox/Viewing conditions (Weekly)
6. AOP Mode and SNR Check (Monthly)
7. Visual Checklist (Monthly)
8. Repeat Analysis (Quarterly)
9. Compression force (Semi-annual)

QA Tests – Medical Physicist

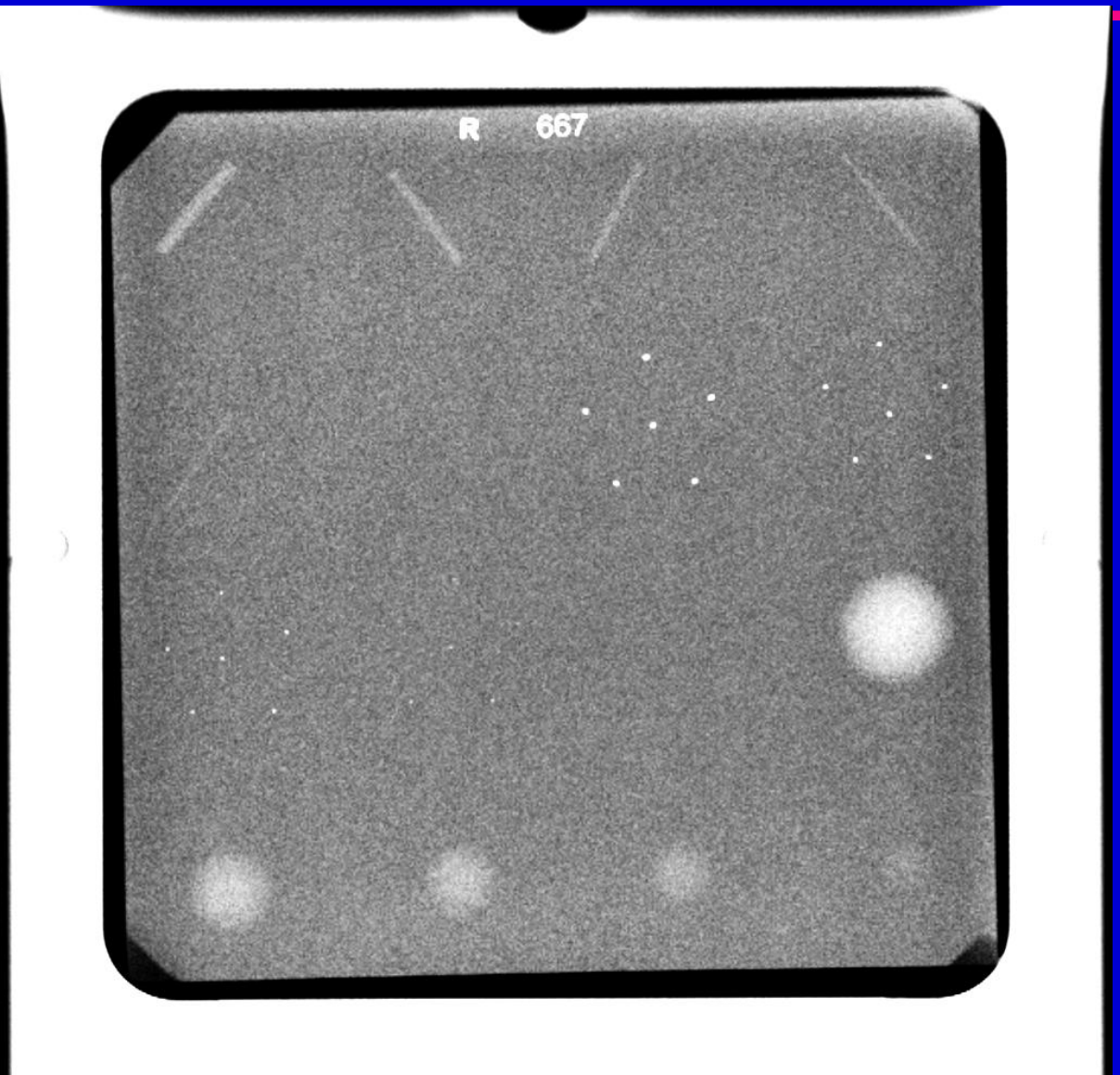
Film/Screen (Annual, Semi)

1. Mammographic Unit Assembly
2. Collimation
3. Evaluation of Focal Spot Performance
4. AEC Performance
5. Uniformity of Screen Speed (Semi)
6. Artifact Evaluation
7. Phantom IQ
8. kVp Accuracy/Reproducibility
9. Beam Quality (HVL)
10. Breast ESE, MGD, Rad. Output Rate
11. Viewbox Lum./Room Illumin.

Digital (Annual)

1. Mammographic Unit Assembly
2. Collimation
3. Eval. of Focal Spot/Sub-system MTF
4. AOP Mode/SNR
5. Flat Field and Phantom IQ
6. Artifact Evaluation
7. CNR/MTF Measurement
8. kVp Accuracy/Reproducibility
9. Beam Quality (HVL)
10. Breast ESE, MGD, Reproducibility
11. Radiation Output Rate
12. Viewbox Lum./Room Illum.
    Monitor Eval./Calibration

IQ Evaluation: ACR Phantom



- Fibers
  - 1.56 – 0.4 mm nylon
- Masses
  - 2.0 – 0.25 mm
- Microcalcs:
  - 0.54 – 0.16 mm

Phantom score: Pass

Fibers	≥ 4
Masses	≥ 3
Microcalcs	≥ 3

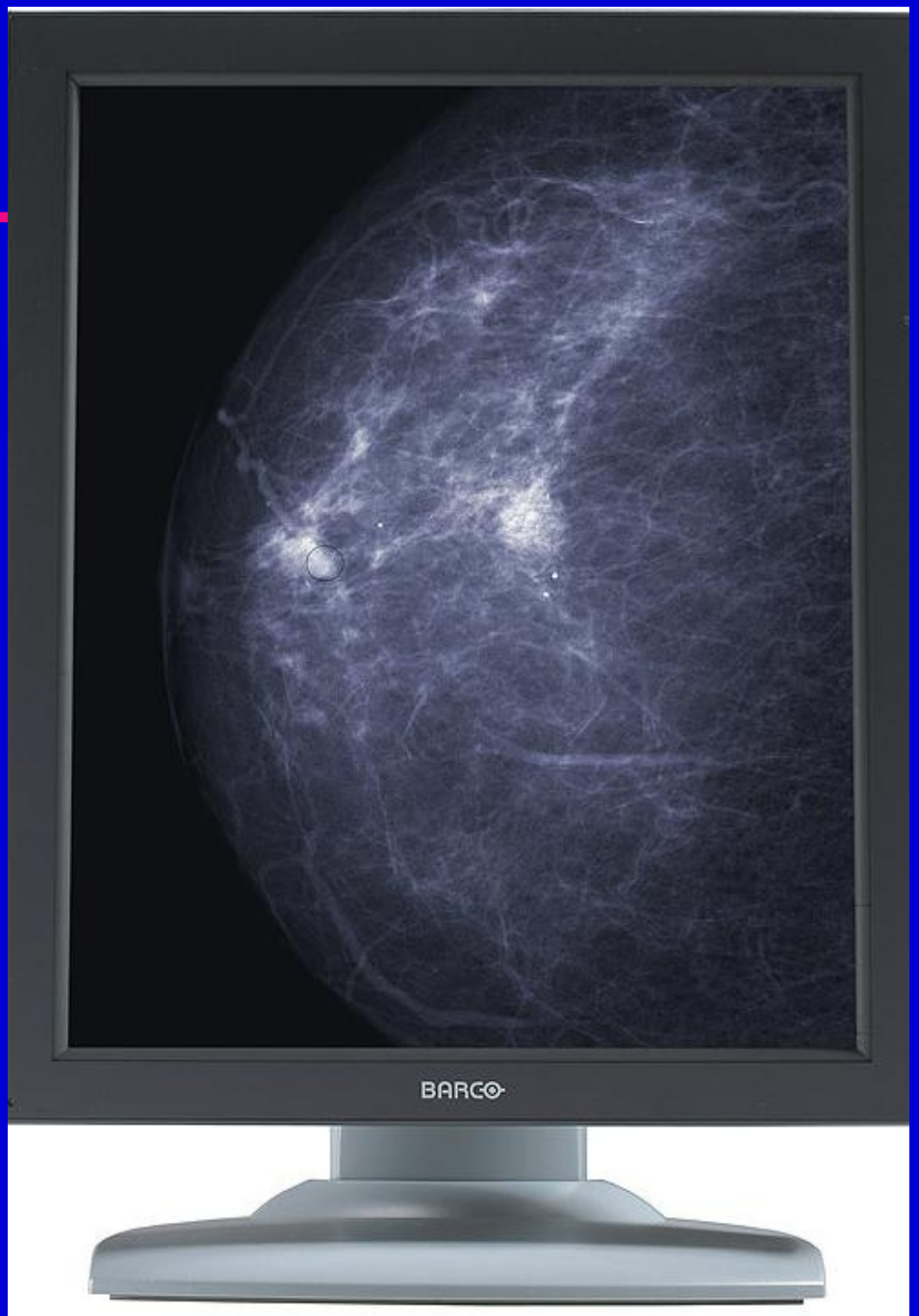
Mammography Viewbox

- **Film displayed on mammography viewbox**
  - Usually 2 panels, CC/MLO projections, Left/Right
  - Previous/current films comparison
  - No window/level adjustment; bright light (Skin line)

- **Viewbox/Reading room specifications**
  - Luminance: light emitted by surface (viewbox)
  - Measured at different locations on viewbox with photometer (physicist test)
  - Acceptable luminance: > 3000 cd/m^2 (876 fL)
  - Typical luminance: 1500 – 3000 cd/m^2

  - Illuminance: light falling on surface (viewbox)
  - Measured at viewbox and in room (ambient)
  - Acceptable level: ≤ 50 lux
  - Minimal amount of ambient light

Digital Workstation



Digital Workstation

- **Display Monitors**
  - High Contrast, High Resolution, LCD flat panel
  - Resolution: 5 Mpixel 2560 x 2048
  - Left/Right monitors side by side
  - Manipulation of brightness/contrast, format, MAG, Image tools
  - Auto-calibration, QA

- **Image storage/archive**
  - Image size 4 – 5 Mpixels (1900 x 2300 pixels)
  - Storage: Several MB per image
  - AWS, RWS workstations – images sent to PACS
  - Hard copy: Laser printer

Q.A. Measured Data

- **Compare mammo. units**
  - **inconsistencies**
  - **artifacts**
  - **overall image quality, dose**

- **Same mammo. unit**
  - **review data over time; systematic problems**
  - **compare measured data to manufacturer requirement**
  - **consistent problem may require field service (recalibration)**

Q.A. Evaluation Examples

- **Technologist**
  - **Film: Processor Q.C.**
    - » **maintain consistency of film density/contrast**
    - » **reduce artifacts**
  - **Compression**
    - » **firm compression essential to decrease scatter**
    - » **reduce dose, motion**
  - **Phantom image: overall image quality**
- **Medical Physicist**
  - **Measurement of radiation dose (MGD)**
  - **AEC Performance: consistent exposures**
  - **Beam quality (HVL): radiation dose, image contrast**
  - **Non-uniformity across digital detector (pixel calibration)**