Beth Schueler, Ph.D.
Mayo Clinic Rochester

THE ART OF THE IMAGE IN MAMMOGRAPHY
Artifacts In 2D And 3D Breast Imaging: Their Origin, Presentation, And Remediation
What will be covered:

- 2D FFDM
- Tomosynthesis
- Contrast-enhanced spectral mammography
Artifact Presentation

- In clinical images
- In flat field artifact QC test
- In ACR phantom images
FFDM-2D Artifacts
Cause:

- Detector readout malfunction, failure of switching gate lines

Resolution:

- Replace detector
Cause:
- Dead pixel cluster resulting in charge build-up affecting signal in neighboring pixels

Resolution:
- Replace detector
Cause:
- Dead pixel
  - Troubleshoot by re-imaging phantom in a different location on the detector or perform an artifact test
  - Dead pixels may be either minus or plus signal

Resolution:
- Map out dead pixel (service function)
Dead Pixel Removal

- Map is created that replaces the specified pixel value with the average of surrounding pixels
Artifact Evaluation QC Test

- Manufacturer test method
  - Uniform phantom
  - Acquire image with typical clinical technique
  - View image with specified W/L
  - Repeat for different anode/filters and mag mode
Artifac Evaluation QC Test

- Zoom and pan image looking for artifacts
- Use ROI utility if available
Artifact Evaluation QC Test

- 2016 ACR Digital Mammography QC Manual
  - Artifact evaluation part of phantom IQ test
Artifact Evaluation QC Test

- W/L to optimize visualization of test objects
- View as entire phantom
- View as full resolution (1 display pixel = 1 image pixel)
- Repeat for other anodes/filters, mag mode
Cause:
- Dead pixel cluster with averaging correction applied

Resolution:
- Adjust pixels included in the averaging correction in the dead pixel map (service function)
- If cluster is large, replace detector
Cause:

- Debris embedded in MammoPad breast cushion attached to phantom
  - Troubleshooting: If an artifact moves with the phantom, debris on phantom or wax insert is likely

Resolution:

- Replace MammoPad
Cause:
• Debris on phantom during gain calibration resulting in a plus density artifact

Resolution:
• Recalibrate detector
  ○ Ensure phantom and detector cover are clean
  ○ Carefully review flat field images acquired during gain calibration
Cause:
- Dead line in detector

Resolution:
- Map out dead line (service function) or replace detector
Dead Line Artifact Detection

- Image mesh at 45 deg angle (screen-film contact test tool)
- Corrected dead lines are visible as discontinuities in mesh
Dead Pixel/Line Specification

- DirectRay Detector
  - < 80 defective clusters (contiguous dead pixels)
  - < 20 defective lines (gate line or source half-line)
    - No adjacent defective gate lines
    - No more than 2 adjacent defective source half-lines
  - < 3397 defective pixels
Cause:
- Intermittent electromagnetic interference

Resolution:
- Eliminate cause of interference
  - Replacement of the high voltage supply resolved this particular case
  - Other references attribute artifact to
    - cooling fans (Ayyala et al, Radiographics 2008)
    - external magnetic fields from an adjacent transformer (Jiang et al, AAPM 2017)
Causes:
- Degradation of detector array coating

Resolution:
- Replace detector
Image acquired immediately before
○ Ghosting
  ○ Residual image of the previous exposure is visible
  ○ Direct conversion detector has reduced x-ray sensitivity in areas of high exposure
  ○ Occurs especially with high technique factors

○ Resolution:
  ● Increase time interval between images
  ● Modify detector refresh rate
Ghost Image Evaluation Test

Wait 1 min between exposures
Ghost Image Evaluation Test

- Ghosting index = \(\frac{(S_3-S_1)}{(S_1-S_2)}\)
  - Should be < 0.3
Cause:

- Visible grid
  - High transmission cellular (HTC) grid was stationary for a portion of the exposure
  - Intermittently seen in clinical images

Resolution:

- Service to the bucky mechanism resulted in consistent grid movement
Gain Calibration display
Cause:
- Visible HTC grid during gain calibration
- Grid stationary during a portion of the exposure

Resolution:
- Service adjustment of exposure timing to eliminate exposure when grid is stationary at end of travel
- **Cause:**
  - Debris on filter, included in gain calibration, then shifted slightly

- **Resolution:**
  - Clean debris off filter, repeat gain calibration
Cause:

- Error in skin line image processing clips tissue in the image

Resolution:

- Adjust sensitivity of skin line detection algorithm
Original

100 mm thickness, 44 kV

Retake after repair

58 mm thickness, 30 kV
Cause:
- Error in compressed breast thickness readout resulted in high kVp selection and detector burnout

Resolution:
- Recalibrate compressed breast thickness readout
CR Artifacts
Cause:
- Debris or defect on CR imaging plate

Resolution:
- Clean imaging plate using method recommended by manufacturer
- If artifact cannot be removed, replace imaging plate
Tomosynthesis (DBT) Artifacts
Cause:
- Artificial low density surrounding high density objects along the scan direction ("halo" artifact)
- Due to limited angular range in acquisition sweep

Resolution:
- Various reconstruction algorithm modifications have been proposed to reduce appearance
  - Based on removing high contrast object from the projection images prior to reconstruction, then adding back into slice images
Ref: Wu et al, Med Phys 2006
Cause:
- Out-of-plane high contrast object is visible as “zipper” artifact along the scan direction
- Caused by limited angular range in acquisition sweep

Resolution:
- Same solutions as halo artifact reduction
Cause:
- Limited angular range in acquisition sweep results in “staircase” artifact at the edge of reconstruction field

Resolution:
- Same solutions as halo artifact reduction
False calcifications on a 2D image synthesized from tomosynthesis slices

- **Cause:**
  - Overlapping dense ligaments in slice images combine to appear as calcifications

- **Resolution:**
  - Modification of 2D image synthesis algorithm
Contrast-enhanced Spectral Mammography (CESM) Artifacts
CESM Method

6 minutes
Low Energy
28-32 kVp
Rh or Ag filter

High Energy
45-49 kVp
Cu filter

Subtraction image
Low energy image

Subtraction image

Reference: Bhimani et al, Acad Rad 2017
Cause:
- Patient motion between the low and high energy exposures

Resolution:
- Motion more likely due to dual exposure method. Adequate compression and patient instruction needed.
Low energy image

Subtraction image

Calcification

Artifact

Reference: Bhimani et al, Acad Rad 2017
Cause:

- Iodine contrast splattered on breast tray
  - Iodine visible on high E image only, appears white on subtracted image
  - Note that calcifications appear dark on subtracted image

Resolution:

- Disconnect power injector from patient away from the mammography unit. Wipe breast tray and paddle before imaging.
Conclusions

- Artifacts may mimic or mask image detail in mammograms
- Becoming familiar with potential artifacts – their appearance, cause and resolution – is helpful for image quality optimization
References:

- 2016 Digital Mammography Quality Control Manual, American College of Radiology