DIGITAL BREAST IMAGING INFORMATICS:

CONSIDERATIONS FOR PACS ADMINISTRATORS

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Digital Breast Imaging

- Digital Mammography +/- CAD
- Digital Breast Tomosynthesis (DBT)
- Breast ultrasound – 2D and 3D
- MRI – Dynamic Contrast +/- “CAD”
- NM, PET, specific tracers
- “Exotic” modalities – optical tomography
Mammography is DIFFERENT!
Mammography Differences

- Very highly regulated – MQSA in US
- Relatively poorly reimbursed
- Screening is insensitive & non-specific
- Screening -> mortality reduction
- Frequently litigated
- Short read times (esp. screening 1-2min)
- Relatively large projection images
Mammography Differences

- Stylized reading process (hanging)
- Pixel matrix exceeds display matrix
- Features may be one pixel in size
- Grayscale rendering is demanding
- CAD is often used
- Both raw and processed images needed
- May need reprocessing
Mammography Differences

- May need extra views - wet read/recall
- May need additional modality (US, MR)
- May need biopsy
- Priors are vital – film or (outside) digital
- Must give patient CD / interpretable film
- Lossy compression forbidden
- Reporting stylized & letter required
Regulations - MQSA

- URL for MQSA questions:
  - [http://www.fda.gov/CDRH/mammography/robohelp/START.HTM](http://www.fda.gov/CDRH/mammography/robohelp/START.HTM)
- E.g., under “Transfer of Records” …

**Question 4:** With the introduction of Full Field Digital Mammography, what constitutes a mammogram for retention and transfer purposes, the digital data or the hardcopy film?

**Question 5:** We have an FFDM unit and do not keep hardcopy of our exams (i.e., we retain the images electronically). When patients request the release of their exam, we create a hardcopy for them. May we charge the patient for the cost of creating the hardcopy?

**Question 6:** Can a facility use lossless compression to transmit images to the patient or other medical institutions for final interpretation?

**Question 7:** Can a facility use lossy compression to transmit images to the patient or other medical institutions for final interpretation?
Projection Image Size

- One image
  - 1914x2294 ≈ 4.2 MB
  - 3328x4096 ≈ 13 MB
  - 4095x5625 ≈ 22 MB

- Lossless compressed 5:1
  - From 0.84 to 4.4MB

- Four views, both For Processing and For Presentation (8 images) in one study
  - 33.6 to 176MB uncompressed
  - 6.7 to 35.2MB lossless compressed
Impact of Image Size

- Affects long term archive, interchange media
- Impact on workstation performance
  - transfer from server to workstation (network)
  - transfer from disk to RAM to frame buffer
- Users alternate between hanging steps
  - tab back and forth between layouts instantly
- Work-list based pre-loading to disk/RAM
  - next case ready and waiting instantly
Reading Process & Layout

- 4 screening views L/R CC/MLO +/- prior
- Flipped correctly back-to-back
- +/- CAD marks
- Overview (gestalt) on two monitors
- Fit breast to screen – rest same size
- Detailed comparison (1:1 pixels)
- Film comparison (true-size)
- Extra views (mustn’t be skipped)
Workstation Requirements

- Size - current and priors same size, fit to screen, true size
- Orientation - correctly flipped
- Annotation - not on the breast; enough to QC
- Justification - back-to-back with no gap
- Grayscale contrast - as the vendor intended
- Background air suppression - for windowing & inversion
View - CC Laterality - Right

→ Posterior

View - CC Laterality - Left

→ Anterior

Right

Layout without justification
Original

Outline
1:1 acquired to display pixel 5MP different sensors

Original  Outline  Boundary
Same size
Same size and fitted to screen
IHE Mammo Profile

- Defines the minimum display features required in all Image Display actors
- Defines what DICOM attributes shall be used to implement them
- Defines which DICOM Attributes the Acquisition Modality must populate
- Also addresses printing
Prior (above) and Current (below) images are of different sizes and inconsistent orientation

Prior (above) and Current (below) images are of same size and consistent orientation
Grayscale Contrast

- Transform stored pixels to display values
- Acquisition vendors use:
  - linear windowing
  - sigmoid function windowing
  - lookup table to encode function
- Unsatisfactory appearance if ignored
- IHE profile requires support for all three
- IHE also requires these be user adjustable
- DICOM GSDF-calibrated display is required
- Not burdensome for addition to typical PACS
Sigmoid curve encoded as specified shape with window parameters

Pixel Value (LUT Index)

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P-Value

Window Center

Window Width
**Layout and Annotation**

- DICOM Mammo object uses codes
  - for View and Modifier
  - needed for flipping to A\F orientation
  - needed for required standard label ("LMLOID")
  - e.g. Left MLO Implant displaced:
    ("R-10226",SRT,"MLO") ("R-102D5",SRT,"ID")
- General purpose viewers tend to hang based on plain text (like series description)
- Need mammography-specific programming or scripting to support required functions
Annotation

- MQSA
- ACR Quality Manual Requirements
- Interpretation, QC and problem solving
- Dose awareness
- Must not overlay/obscure breast tissue
- Gestalt impression during overview
- Must not hide features under annotation
Neither DICOM nor IHE defines Series
- each image may be separate series
- one series for set of four screening For Presentation views
- four series with For Presentation and For Processing pairs in one series for each view

Robust viewer must not make assumptions about series organization

IHE profile requires series independence
Workflow

- Scheduled workflow for modality
  - IHE SWF +/- mammography specifics (new in 2008)
- CAD workflow
  - de facto standard “push” workflow
- Reporting workflow
  - no accepted standards
- Image distribution workflow
  - IHE PDI
- Result distribution workflow
  - no accepted standards
- Importation of priors workflow
  - IHE IRWF
- Objective – improve sensitivity
- Find and mark suspicious locations
- Two primary informatics problems
  - workflow – movement of images & results
  - result encoding & display

*Results need to be visible during read*
CAD “Push” Workflow

- **Acquisition modality produces**
  - For Processing images -> CAD
  - For Presentation images -> human reader

- **CAD server**
  - passively receives images
  - when to start CAD ?
  - when to send CAD results ?

- **Workstation (+/- PACS) displays**
  - For Presentation images
  - with & without CAD marks
  - when is exam “ready to read” (all images/CAD available) ?
The Medicine Behind the Image

Mammography

Mammography CAD

For Processing

CAD Server

For Presentation

Workstation

RADPHARM
The Medicine Behind the Image

Mammography

Archive

Manager

For Processing

CAD Result

For Presentation

CAD Server

For Processing

CAD Result

For Presentation

Workstation
CAD Encoding

- DICOM Structured Report
  - Mammography CAD SR SOP Class
  - co-ordinates on For Processing image
  - coded classification (mass, micro-calcification)
  - required in all Image Displays by IHE
  - format of displayed marks is not defined/encoded

- Support issues in non-IHE Image Display
  - no support in “ordinary” viewers/PACS
  - poor support – crash if SR too complicated
  - poor filtering of complex content
  - resolving UID reference to For Processing image
Non-IHE CAD Workarounds

- **Deployment**
  - CAD server creates something else than SR CAD
  - convertor box can change SR to something else

- **Alternative encodings**
  - separate Presentation State object
  - add 6000 overlay to new For Presentation image
  - burned into pixels of another For Presentation image
  - proprietary internal PACS annotation

- **Issues with workarounds**
  - reader still needs to be able to turn marks on/off
  - size/shape/behavior of marks may affect interpretation
CAD Archival

● Additional issue of what to archive?
  • input data (For Processing Images)
  • CAD result itself

● Why archive?
  • reprocess next year -> better change detection
  • “audit trail” to support decision making
  • retrospective CAD supports interpretation (legal case)
  • clinical trials

● Why not archive?
  • space (may matter for images, CAD size trivial)
  • “audit trail” of decision with unfortunate outcome
For Processing/Presentation

- DX family of objects, including mammo
  - For Presentation – processed, ready to view
  - For Processing – raw, not viewable
- All modalities & displays
  - shall support For Presentation
  - may also support For Processing
- CAD requires For Processing
- If user wants different (proprietary) processing
  - reprocess at modality
  - send For Processing to (proprietary) workstation
- Interchange (media) requires >= For Presentation
Computed Radiography (CR)

- Later to market in USA than fixed detectors
- USA release supports DICOM MG
- Separate devices expose and read cassettes
- Makes it challenging to populate DICOM header
  - demographics, dates, IDs
  - view and orientation
  - technique and dose
- Vendor approaches
  - bar coding
  - retrofitting generator to acquire data
- User should still insist on IHE Mammo compliance
Compression

- Lossless compression only
- No lossy compression for interpretation
- No studies yet on lossy compression
  - Very encouraging results from digitized film
  - Still no ROC study on FFDM data
  - Confounded by different vendor characteristics, detector size, processing
  - DMIST data set still sequestered and by now probably obsolete
Lossless compression

- 20 pairs (40 images)
  - of For Processing and For Presentation
- Three vendors
  - 4 pairs Lorad (1 patient, 4 views)
  - 4 pairs Fischer (1 patient, 4 views)
  - 12 pairs GE (3 patients, 4 views each)
Lossless Compression - Compression Ratios

![Bar chart showing compression ratios for various compression schemes.

The x-axis represents the compression schemes, including Entropy, LGZIP, BGZIP, LCOMP, BCOMP, LBZ2, BBZ2, JPL1, JPL2, JPL3, JPL4, JPL5, JPL6, JPL7, JPEG-LS, and JPEG 2000.

The y-axis represents the compression ratio compared to 2 bytes, ranging from 0 to 7.

Legend:
- Yellow: Both
- Orange: For Presentation
- Blue: For Processing

The chart compares the compression ratios for different schemes, with various schemes showing different levels of compression efficiency.]
Lossless compression

- For Presentation > For Processing
  - less noisy
- All compress extremely well
  - mostly air
- Considerable variation
  - size of breast
- JPEG-LS and JPEG 2000 best
  - mean CR 6.27 and 6.25 For Presentation
- Lossless JPEG (SV1) poor
  - mean CR 4.41 For Presentation
  - no run length compression, so poor for large areas of air
Variation in compressibility

JPEG-LS Lossless

Best - CR 12.9

Worst - CR 3.19
Transfer between facilities

- Special mammography requirements
- Priors are essential
- Combined film/softcopy undesirable
- Women move (job, insurance, referrer)

Therefore need standard, portable digital transport mechanism

Nationwide/regional imaging network is long term

Portable digital media is currently the only answer
Media for mammography

- Standard image format - DICOM Mammo Image
  - For Presentation only, or For Processing as well?
- Standard media - CD or DVD
  - How many images (visits) will fit? Enough.
- Compression
  - None, lossless (not lossy)? Which scheme? PDI - None
- CAD
  - As DICOM Mammography CAD SR?
  - As DICOM Presentation State? Both?
- Radiologist’s reports and annotations
  - DICOM Mammography SR?
  - Other - plain text, HTML, HL7 CDA?
Many CD viewers not mammo aware

Suitability for referring doctor
  - e.g., surgeon for biopsy/lumpectomy

Support for localization of abnormality
  - Presentation States

Importation expectation avoids issue
  - surgeon’s own viewing system
  - next year’s radiologist’s own workstation

No proprietary formats & viewers !@#$
“For purposes of transferring films, the facility must be able to provide the medical institution, physician, healthcare provider, patient or patient’s representative, with hardcopy films of final interpretation quality or, when it is acceptable to the recipient (e.g., a transfer between two FFDM facilities), with original or lossless compressed full field digital images electronically.”

Questions about MQSA 900.12(c)(4)(ii),(iii)
Printing

- Must be able to print interpretation quality film
- Physical size for hanging
- True size, for biopsy, comparison as priors
- Annotation, per MQSA and quality manual
- Grayscale 12 bits and as per DICOM GSDF
- Dmax sufficient for mammo (IHE > 3.5)
- Insist on IHE Mammo profile for printing
- Likely requires a dedicated mammo printer with the appropriate film size(s)
Other modalities

- “Multi-modality” workstation
- Isn’t that what a PACS workstation is?
- Breast ultrasound, same as any other
- Breast MRI more difficult
  - dynamic contrast acquisition
  - requires analysis of time-intensity curve
  - so-called DCE-MR “CAD” application
  - yet another non-integrated 3rd party device?
  - “plug-in” architecture – DICOM WG 23
The Medicine Behind the Image

Tomosynthesis

- Multiple projection images
- Reconstructed to make “slices”
- And you thought FFDM images were big!
- Impact of large size
  - archive and interchange media
  - network retrieval on demand to disk and RAM (pre-fetch)
  - speed of scrolling though slices
  - 20MB per slice, not 0.5MB CT, and 5MP display
- DICOM standard format ballot finished
- Vendors may go to market with proprietary format 😞
- Demand DICOM in your contract in reasonable time
Conclusion

- Mammography is different
- 3rd party workstations are capable, but not integrated without reading worklist
- PACS workstations are getting there
- Insist on IHE Mammo profile, now or in reasonable time per contract with penalties
- Deploy CAD “properly”, with SR CAD
- Archive everything, and do it losslessly
- Produce DICOM/IHE PDI compliant media
- Print interpretation quality films, true size, annotated
- Prepare for tomo, and be afraid!
IHE Resources

- IHE Mammography web site
  - http://www.ihe.net/Mammo/
- IHE Mammography Profile in Radiology TF
- Going Digital: An IHE Guide for Mammography
  - http://www.ihe.net/Mammo/going_digital_mammography.cfm
- IHE Mammography User's Handbook
  - http://www.ihe.net/Resources/handbook.cfm