Clinical and management aspects of digital imaging and PACS

พญ. จามรี เชื้อเพชระโสภณ
นายกรัฐมนตรีสมาคมแห่งประเทศไทย
chamareec@gmail.com
www.radiologythailand.org
Digital imaging

• Abbreviation and terminology

• PACS and related issues
Digital imaging

• ACR
  – American College of radiology
• CPT
  – Current Procedural Terminology
• EMR (EHR)
  – Electronic Medical Records (Electronic Health Records)
• HL 7
  – Health Level Seven
• HIPAA
  – Health Insurance Portability and Accountability Act
• IHE
  – Integrating the Healthcare Enterprise
Digital imaging

- **HIS**
  - Hospital Information System
- **RIS**
  - Radiological information system
- **PACS**
  - Picture Archiving and Communication System
- **SNOMED CT**
  - Systematized Nomenclature of Medicine
- **ICD 10**
  - International Classification of Diseases
- **IEEE**
  - Institute of Electrical and Electronics Engineers, Inc
- **LOINC**
  - Logical Observations: Identifiers, Names, Codes
Digital imaging

- Modalities
  - Types of Equipment
- Modality worklist
  - List of patients for that modality
- Workflow
- PACS administrator
Digital imaging

- The Digital Imaging and Communications in Medicine (DICOM) Standard
  - was developed for the transmission of images and
  - is used internationally for Picture Archiving and Communication Systems (PACS).
- This standard was developed by the joint committee of the ACR (the American College of Radiology) and NEMA (the National Electrical Manufacturers Association) to meet the needs of manufacturers and users of medical imaging equipment for interconnection of devices on standard networks.
The ACR Practice Parameters and Technical Standards help advance the science of radiology and improve the quality of service to patients. They promote the safe and effective use of diagnostic and therapeutic radiology by describing specific training, skills and techniques. Learn more »

The ACR Practice Guidelines and Technical Standards for 2013 are currently presented on the website.

The 2014 ACR Annual Meeting and Chapter Leadership Conference (AMCLC) had many interesting developments. First, the name “Practice Guidelines and Technical Standards” has been changed to “Practice Parameters and Technical Standards”. Second, the CT Lung Cancer Screening Parameter document was adopted as amended at AMCLC and is currently available on this website. The rest of the 2014
What is PACS?

**P: Picture:** *Images file, Movie file, VDO file & Reports*

**A: Archive:** *Online, Near line, Offline*

**C: Communication:** *Display, Networking, Transfer Protocols*

**S: System:** *Components & Architecture*
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
Image Acquisition

- THINK DIGITAL!!
- DICOM 3.0 STANDARD, Gateway Interface
- Computed Radiograph (CR)
- Direct Radiograph (DR)
- CT, MRI, PET CT
- Digital Fluoroscope, Digital Angiogram
- Ultrasound, Mammogram, Nuclear medicine,
- Scanner, Video capture
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
Properties of image

- Bit depth (9 bits or higher for digital mammogram)
- Grayscale or color
- Resolution in pixel
  - Example image size of mammogram = 4k x 5k x 12 bit = 30 MB
Image Resolution/ Bit depth

**U/S**
- 256 x 256
- 8 bit
- 65 KBytes

**DF**
- 1k x 1k
- 10 bit
- 1.25 MByte

**CR**
- 2k x 2.5k
- 12 bit
- 7.5 MByte

**CR Mammogram**
- 4k x 5k
- 12 bit
- 30 MByte
Database

CT 512 x 512 x 8 bits
   = 256 KB /images Average 400 images/study = 100 MB

MRI 512 x 512 x 8 bits
   = 256 KB/images Average 400 images/study = 100 MB

Plain film (Plain radiograph)
   = (2K) 2048 x 2048 x12 bits = 10 MB/study

Mammogram 4096 x 5625 x 12 bits
   = 30-40 MB per image x 4-6 Images

Ultrasound, Nuclear medicine, Scanner, Digital Fluoroscope
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
Network

• Acquisition (Modality) network (DICOM 3.0)

• Information network

  (HL-7, IHE – Integrating the healthcare enterprise)

• Architecture (central, distributed)
Central Architecture

- Image Server and Database Manager is the HEART
- Any image, any where, any time
- Unique central copy
- Easy update of data
- Requires high performance servers
- Potential single point of failure at server
- Bandwidth demanding
PACS – Distributed Architecture

- DICOM Modality
- Non-DICOM Modality
- Gateway or Frame Grabber
- Diagnostic Workstations (DICOM)
- Clinical Workstations (DICOM)
- Web Server
- Diagnostic Workstation
- Archive
- CR QA Workstation
- Film Digitizer
- Data Base Server
- RIS
- Computed Radiography
- DICOM Modality
- Web Server
Distributed Architecture

• Exams are routed from modality to selected workstations
• Complex routing algorithms based on department / user preference
• Difficult to support concurrent review of images
• Less destructive for failure at database server
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
File maintenance

• Storage (What needs to be stored?)
• The images expected to be viewed by client view station
• GB, TB, Petabyte
• Everything always online
• In house, Back up
• Cloud technology
Image compression;

- JPEG, JPEG-LS, JPEG-2000 or MPEG
- Reversible (lossless) or irreversible (lossy).
- Current FDA policy does not allow irreversible compression of digital mammograms.
- The burden remains on the responsible physician to assure that the image quality is sufficient to achieve a diagnostically acceptable goal.
ACR

- IT Reference Guide for the Practicing Radiologist: Display
  Published 2013 ©Copyright American College of Radiology

- ACR–AAPM–SIIM PRACTICE GUIDELINE FOR DIGITAL RADIOGRAPHY (revised 2012)

- ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING (revised 2012)

RCR(UK)

- The adoption of lossy image data compression for the purpose of clinical interpretation:
  - The Royal College of Radiologists of UK, April 2008

German

- German commission on radiology protection
The compression ratio recommendations are as follows.

<table>
<thead>
<tr>
<th>MODALITY</th>
<th>COMPRESSION RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest radiography</td>
<td>10:1</td>
</tr>
<tr>
<td>Skeletal radiography</td>
<td>10:1</td>
</tr>
<tr>
<td>CT (all areas)</td>
<td>5:1</td>
</tr>
<tr>
<td>Mammography</td>
<td>20:1</td>
</tr>
<tr>
<td>MR</td>
<td>5:1</td>
</tr>
<tr>
<td>US</td>
<td>10:1</td>
</tr>
<tr>
<td>Digital angiography</td>
<td>10:1</td>
</tr>
<tr>
<td>Radiotherapy CT</td>
<td>No compression</td>
</tr>
</tbody>
</table>

http://www.rcr.ac.uk/docs/radiology/pdf/IT_guidance_LossyApr08.pdf
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
Hard Copy: Film/ Laser printer (Analog)
Soft copy: Workstation (Digital)
Analog vs Digital imaging

- L0 (Luminance of light-box with no film present): 2000 cd/m2
- La (ambient room light reflected by film): 10 cd/m2
- Dmin (minimum optical density obtainable on film): 0.20
- Dmax (maximum optical density desirable on film): 3.00
Analog vs Digital imaging

- Hard copy - $D_{\text{max}}$ determined by a concentration of silver halide on film
  A small influence by ambient light (room light)
  -$D_{\text{min}}$ determined by light box brightness and film fog

- Soft copy - $D_{\text{max}}$ determined by the ambient light and reflectivity of the tube surface
Digital Image display

- Workstation characteristics
- Display characteristics
Workstation characteristics

• Graphic bit depth
• Liquid crystal display (LCD) technology
• Light-emitting diode (LED) technology
• Graphic interface
• Image presentation size
• Presentation support features
• Ergonomic factors
Image Resolution/ Bit depth

U/S
256 x 256
8 bit
65 KBytes

DF
1k x 1k
10 bit
1.25 MByte

CR
2k x 2.5k
12 bit
7.5 MByte

CR Mammogram
4k x 5k
12 bit
30 MByte
Image presentation size

• Good visualization of the full scene is achieved when the diagonal display distance is about 80 percent of the viewing distance.

• At 2/3 meter, this corresponds to a diagonal size of 53 cm (21 inches). (Monitors with a pixel array size of 1,500 x 2,000 and a pixel pitch of 0.210 will have a diagonal size of 52.5 cm)
Display characteristics

Luminance response,

Pixel pitch and display size
Display characteristics

Luminance response,

Ambient luminance
Minimum luminance
Maximum luminance
ยกตัวอย่างความสว่างของจอ

• diagnostic monitors used for interpretation should be at least 350 cd/m2
• For the interpretation of mammograms, Lmax should be at least 420 cd/m2

ยกตัวอย่างความสว่างของห้อง (Ambient light)

• General diagnosis 50 LUX
• Mammogram 20 LUX
Status
Review the status of your workstation and the QAWeb Server connection

Configuration
See information about the configuration of your display system, and adjust local settings

Test Patterns
Judge the display system’s quality by reviewing common used test patterns

Service Level
Review your service level settings, and upgrade your service level
Result Details

Calibration Policy

   Display Function : DICOM GSDF
   Luminance : Maximized Lifetime
   Chroma : Native White
   Black Luminance : Native Black
   Reading Room : X-Ray Diagnostic Reading Room
   ULT : Disabled

Calibration Parameters

   Method : Full Calibration

Calibration Values

   L min : 0.45 Cd/m²
   L max : 499.82 Cd/m²
   L ambient : 0.05 Cd/m²
   Chroma : x: 0.302 y: 0.326
Display characteristics

Pixel pitch

• The pixel pitch of a monitor determines the maximum spatial frequency that can be presented in an image.

• For monitors used in diagnostic interpretation, it is recommended that the pixel pitch be about 0.200 mm and not larger than 0.210 mm.
Pixel Size = \frac{\text{Image Size (mm)}}{\text{Matrix Size (pixels)}}
<table>
<thead>
<tr>
<th>Model</th>
<th>Screen size</th>
<th>Resolution</th>
<th>Pixel density</th>
<th>Angular pixel density (px/°; at typical viewing distance)</th>
<th>Typical viewing distance</th>
<th>Total pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPhone 6 Plus, iPhone 6S Plus and iPhone 7 Plus</td>
<td>5.5-inch</td>
<td>1920x1080</td>
<td>401</td>
<td>157</td>
<td></td>
<td>2,073,600</td>
</tr>
<tr>
<td>iPad Mini 2, 3, and 4</td>
<td>7.9-inch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iPad (3rd, 4th generation, Air, Air 2, and Pro)</td>
<td>9.7-inch</td>
<td>2048x1536</td>
<td>264</td>
<td>105</td>
<td>70.6</td>
<td>3,145,728</td>
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<tr>
<td>iPad Pro (12.9)</td>
<td>12.9-inch</td>
<td>2732x2048</td>
<td></td>
<td></td>
<td>71.9</td>
<td>5,595,136</td>
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<tr>
<td>MacBook (Retina) 12&quot;</td>
<td>12-inch</td>
<td>2304x1440</td>
<td>226</td>
<td></td>
<td>80.7</td>
<td>3,317,760</td>
</tr>
<tr>
<td>MacBook Pro (3rd generation) 13&quot;</td>
<td>13.3-inch</td>
<td>2560x1600</td>
<td>227</td>
<td></td>
<td>81.3</td>
<td>4,096,000</td>
</tr>
<tr>
<td>MacBook Pro (3rd generation) 15&quot;</td>
<td>15.4-inch</td>
<td>2880x1800</td>
<td>220</td>
<td></td>
<td>79.6</td>
<td>5,184,000</td>
</tr>
<tr>
<td>iMac with Retina 4K Display 21.5&quot;</td>
<td>21.5-inch</td>
<td>4096x2304</td>
<td>219</td>
<td></td>
<td>81.6</td>
<td>9,437,184</td>
</tr>
<tr>
<td>iMac with Retina 5K Display 27&quot;</td>
<td>27-inch</td>
<td>5120x2880</td>
<td>218</td>
<td></td>
<td>84</td>
<td>14,745,600</td>
</tr>
</tbody>
</table>
Technical and radiological image quality **comparison** of different liquid crystal displays for radiology:

Francina EM Dams et al. Medical Physics and Technology, Department of Radiology, Albert Schweitzer Hospital, Dordrecht, The Netherlands

- 3-megapixel Barco®, Eizo®, and NEC® displays and a 6-megapixel Barco display.
- According to the tested criteria, all the displays had comparable image quality; however, there was a three-fold difference in price between the most and least expensive displays.
• With all of the knowledge we have, can we use mobile devices to READ and official report imaging study??

YES, BUT....Considered

Resolution, Ambient, Viewing distance, viewing angle and compression
เมื่อจะมี reading Monitor

• ทราบ workstation and display characteristics ของ monitors
• เตรียมแสงสว่างของห้องให้พอเหมาะ
• เตรียมระยะที่นั่งในการดู monitor
• Calibration monitor สม่ำเสมอ และขอ report ของ calibration
• กรณีให้ vendor ดูแล ต้องขอ report เนื้อหาใน report ที่ควรสนใจ
  – ความสว่างของ backlight, grey scales, bit depth, spatial resolution, death pixels
Components of PACS

• Image Acquisition
• Database
• Network
• File maintenance
• Image display
WHY PACS?
Radiology workflow

• Requests go into radiology department
  – *Something magically happens*

• Images and reports come out
WORKFLOW (Analog)

WITHOUT RIS

WITHOUT PACS
Without RIS without PACS (Analog)
Radiology workflow

• Eliot Siegel:
  – In a film-based environment with no PACS or RIS: request to report; How many STEPS?
    – 59 steps
  – Our study (ultrasound): in a PACS-based environment with an RIS, but no interface between the systems: request to report; STEPS?
    – 32 steps

J Am Coll Radiol 2004;1:824-833
With RIS
Without PACS
RIS without PACS

HIS ↔ RIS + FILMS

Outside Radiology ↔ Radiology Department
Hospital Information System (HIS)

- Hospital information system (HIS)
  - Patient information database
  - *Physician order entry*
  - *Report distribution*
  - Support of Clinical and Medical Patient Care Activities in the Hospital
  - Administration of the Hospital’s Daily Business transactions (financial, personnel, payroll, bed census etc.)
  - Evaluation of Hospital Performance and Cost, and projection of the long-term forecast
Radiology Information Systems (RIS)

• Similar to HIS but of smaller scale

• Link to Hospital Information System (HIS)
  ▪ Order entry
  ▪ Billing and Master Record

• Link to Clinical Management System (CMS)
  ▪ Prefetch for Clinical Visit Scheduling

• Patient demographics
RIS without PACS (Analog)
RIS without PACS
RIS without PACS
Radiology/PACS Imaging

Minutes for Exam/Report Process

![Chart showing minutes for exam/report process in 1999 and RIS, with categories such as Sending Film Report, Collecting, Reading, Sorting, Dark Room, Procedure, and Reception.]
With RIS
With PACS
NOT integrated
With RIS

Referring Clinician
1. Get chart from clerk
2. Write orders in chart
3. Give chart to clerk
4. Fill out study request
5. Ask clerk to call chart
6. Review report on chart

Transportation Aide
14. Transport patient to dept.
32. Transport patient back

Ward Clerk
5. Flag order in chart
6. Place chart in “pending orders” bin
10. Contact radiology with patient info
12. Inform nurse of scheduled study
13. Contact transportation personnel
16. Sort report
17. File reports in chart

Radiology Clerk
11. Schedule patient
15. Look up index card
16. Review results of old exams
17. Give card to film room
21. Place request in sending bin
31. Call transportation
33. Re-file index card

Technologist
22. Position patient for scan
23. Obtain images
24. Mark and label images
28. Check films for quality
30. Post results
37. Verify patient information
40. Review images and reports
41. Complete case
42. Take films to film room
43. Return films to jacket
44. Return jacket to “stack”
52. Review and sign report

Film Room Clerk
18. Check recently printed films
19. Search for films in library
20. Write new study on jacket
35. Compare with old studies
36. Bring films to reading room
49. File report in film jacket

Transcriptionist
45. Retrieve tapes
46. Transport tape for dictation
47. Transcribe and return tape
48. Bring report to film room
50. Bring report to front desk
51. Review report and add diagnosis
53. Take report to Medical Admin

Medical Clerk
54. Sort radiology reports
55. Bring reports to wards

Dark Room Tech
25. Bring films to processor
26. Process films
27. Return films to tech

Nurse
7. Take chart back
8. Document order in chart
9. Ask clerk to schedule study

Radiologist
37. Take films from “stack”
38. Review films
39. Mark films
40. Review images and reports
41. Complete case
42. Take films to film room
43. Return films to jacket
44. Return jacket to “stack”
With RIS, With PACS (not integrated)
With RIS
With PACS
(integrated)
With RIS, With PACS, (integrated)
Planning for PACS: A Comprehensive Guide to Nontechnical Considerations

Mervyn D. Cohen, MB, ChB, MD, Lori L. Rumreich, MBA, Kimberley M. Garriot, S. Gregory Jennings, MD

FAQ

• How long to keep PACS data?
• How many high resolution display monitors need in the hospital?
• How to develop TOR/RFP for PACS?
• PACS: Buy or lease?
• Cloud technology
Take home message

- PACS - Basic knowledge is important
Thank you for your attention.