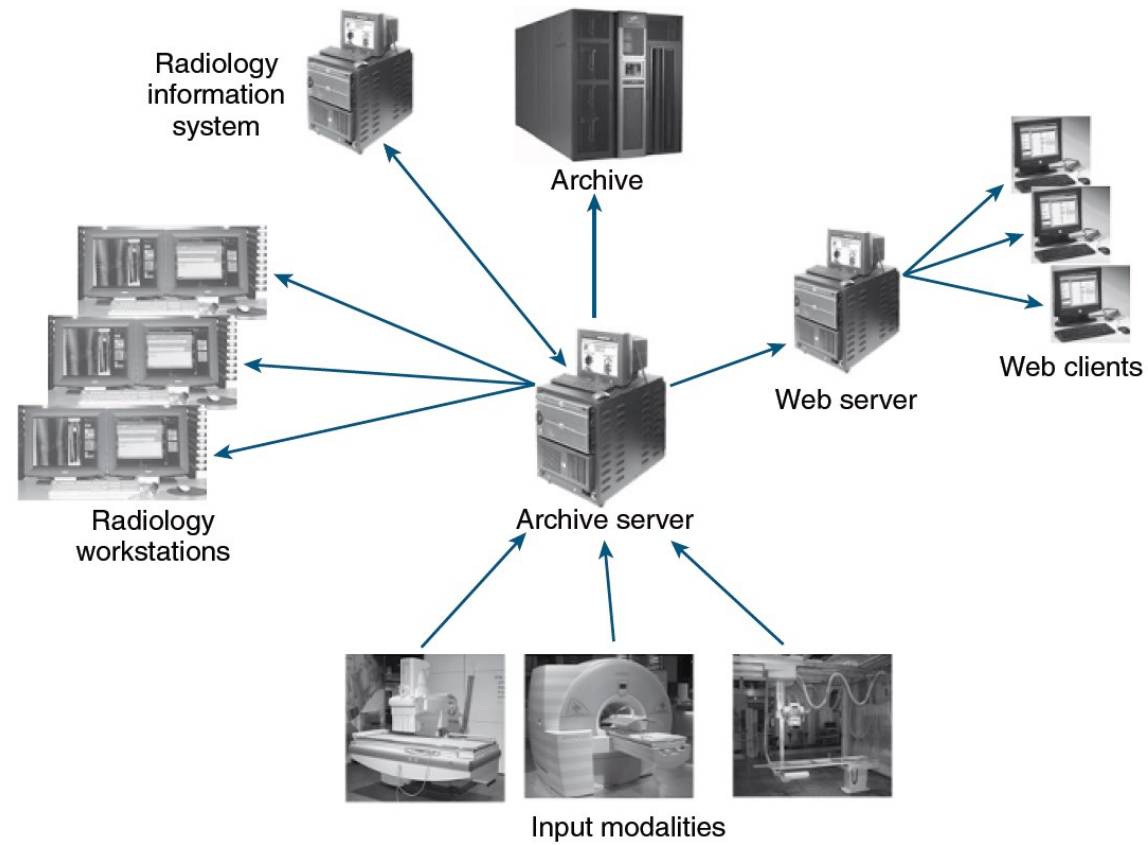# PICTURE ARCHIVING AND COMMUNICATION SYSTEM (PACS)

Prof. Yasser Mostafa Kadah – www.k-space.org

Overview

- PACS consists of digital acquisition, display workstations, and storage devices interconnected through an intricate network
 - Electronic version of the radiologist reading room and the file room.

Workflow

- Workflow is a term that can be used in any industry to describe how a process is done, step by step

- In radiology, workflow describes how examination is done from order entry to transcribed report

- With PACS, it is possible that the time it takes from performing the examination to completing the final radiologist's report is only a couple hours, compared with a couple days for the film-based workflow
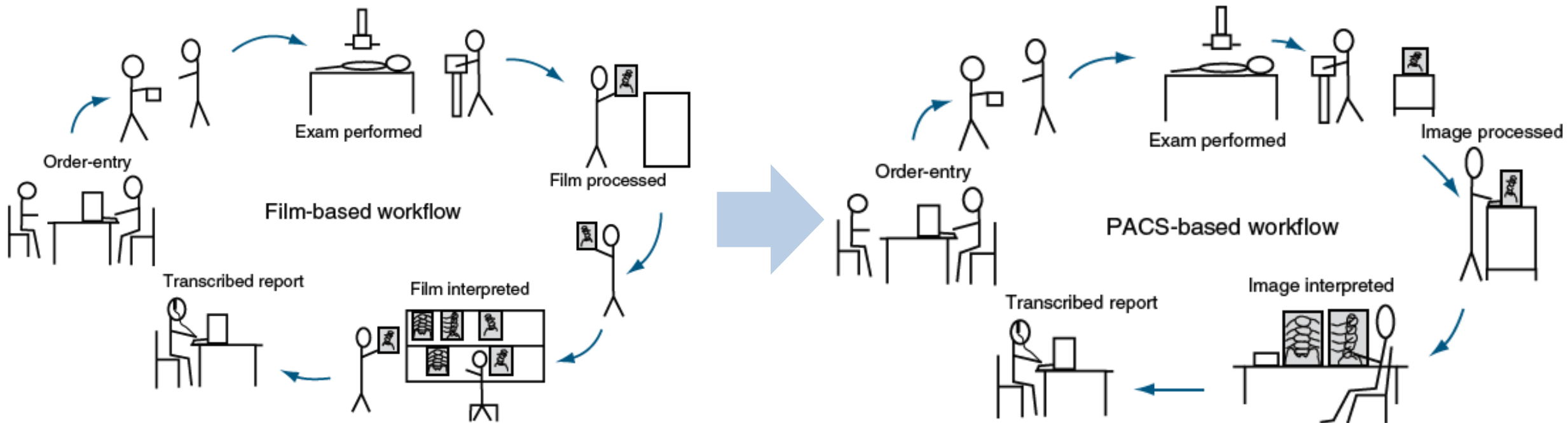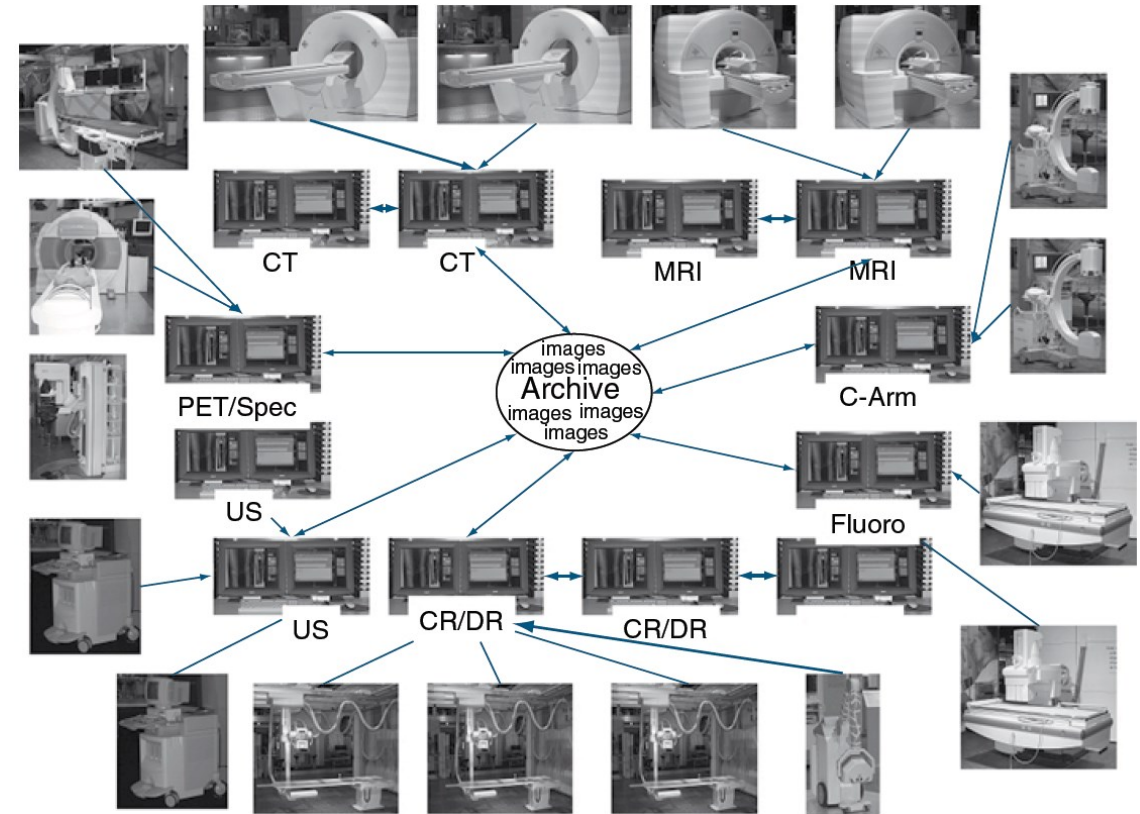
System Architecture

- System architecture can be defined as hardware and software infrastructure of PACS
  - Acquisition devices, storage, display workstations, and an image management system

Client/Server Systems
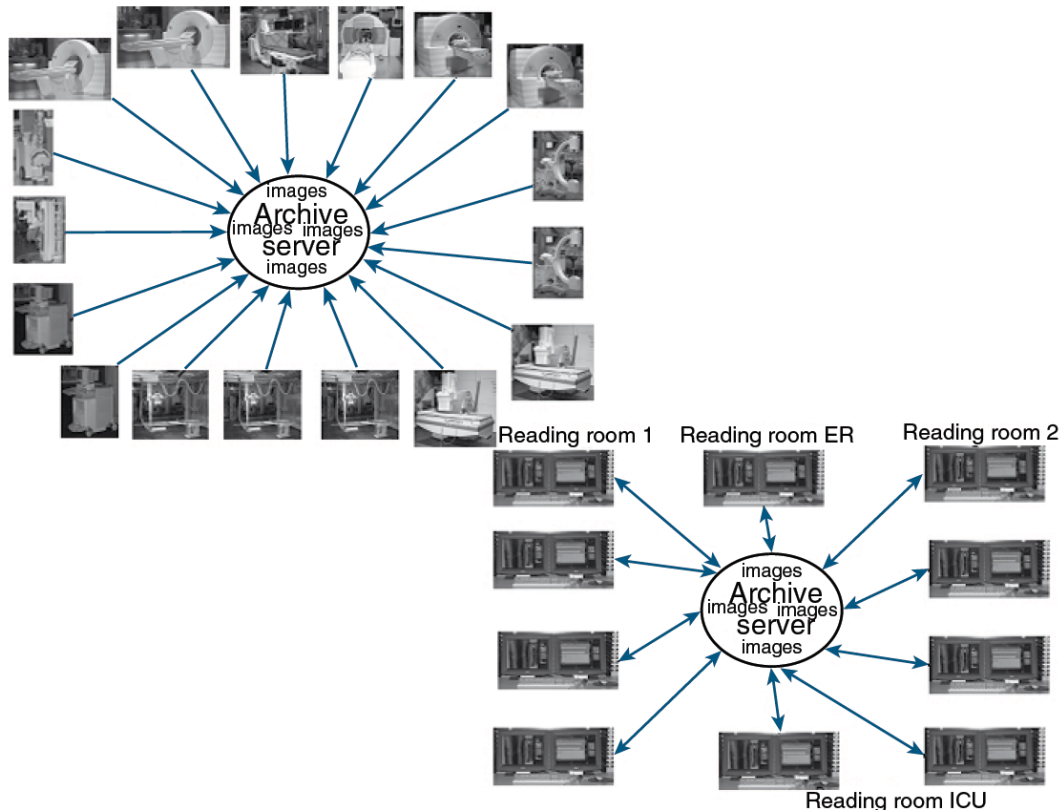
Distributed Systems

Client/Server-Based Systems

☐ Images sent directly to archive server after acquisition and are centrally located

☐ Display workstations work as clients of archive server and access images based on centralized worklist

☐ Healthcare worker at display workstation chooses name from the central list, and archive server sends the image data to display station

☐ After client is finished, image data are flushed from its memory

☐ Most systems allow basic image manipulation at client display workstation or client and changes can be saved on archive server

Advantages
- Any examination sent to PACS is available anywhere without other interventions
- Only one person can open study to read it while others will receive message that study is open and being read
- Old studies are available with the new on archive server and can be accessed from all workstations

Disadvantages
- Archive server is seen as single point of failure – if archive goes down, entire system is down
- System is very network dependent with large volumes of images moving between archive and workstations, that may cause network to slow down
- Archive server handles many requests at once and can become bottlenecked from high volume of requests

Distributed Systems

- Acquisition modalities send images to designated reading station and review stations
  - In some systems, images are sent from modality to archive server, and the archive server distributes images to designated workstation
  - Reading station designations design based on radiologist reading preferences and extensive workflow observation
- Workstations can query and retrieve images from archive and stored locally
  - Images remain on workstation until deleted either by user or by system rules
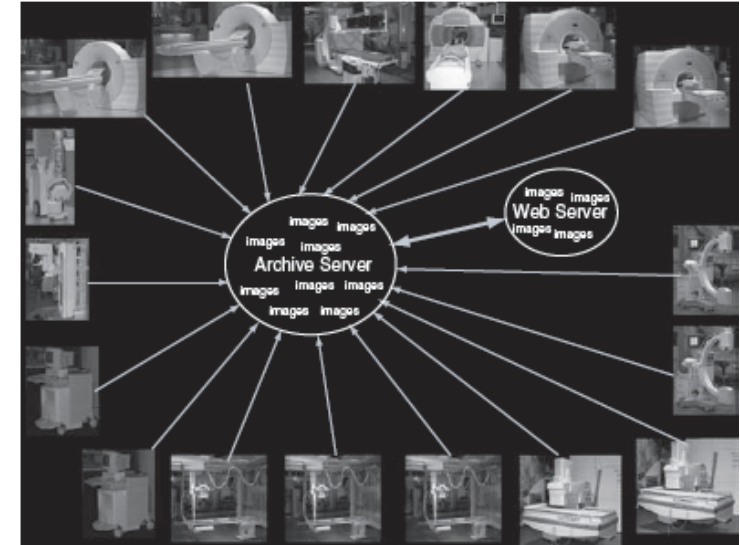
Advantages
- If archive server goes down, local reading at workstations is not interrupted, other than not being able to get historic images
- Because images are distributed to many locations at once, it is less likely that PACS data will be lost
- Less dependence on network for speed

Disadvantages
- Heavy reliance on assumption that distribution of images is being done correctly
- Each workstation has different worklist, and therefore only one person can be working on that list at a time
- Inconvenient to read additional studies that may be designated for another workstation
- Two radiologists can read same examination

Web-Based System

☐ Similar to client/server system in data flow with significant difference that both images and application software for client display are held centrally at archive web server

▫ In client/server system, client has application software locally, and only images are held at archive server


Advantages
- Client hardware can be anything that supports appropriate web browser (greater flexibility with hardware but disadvantage where displays may not be able to support diagnostic quality
- Same application used on site and at home in teleradiology situations

Disadvantages
- Functionality may be limited because software is not installed locally
- Bandwidth of network connection limits amount of data that can be transmitted for download, and some programs are too large to be transmitted over available installed network
- As with client/server systems, network is the biggest obstacle to performance

Display Workstations

- Interactive part of PACS, consisting of monitor and computer with mouse and keyboard
- Conventional film/screen radiography uses large multiviewer lightboxes to display images
  - Early in the history of PACS, radiologists believed that they needed four to six monitors to match viewing capability they had with lightboxes
  - As radiologists became more comfortable viewing images on monitors, number of monitors required by the radiologists has decreased to average of two (attributed in part to continued development of viewing software and better hardware)
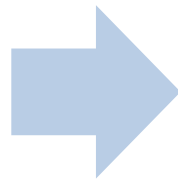
Types of Workstations

- Radiologist reading station
- Physician review station
- Technologist quality control (QC) station
- File room / image management stations

| Radiologist	Physician	Technologist	File Room

Common PACS Workstation Functions

☐ Navigation functions are used to move through images, series, studies, and patients

- ☐ Customizable worklist is used to navigate through patients
- ☐ Hanging protocol is how set of images will be displayed on monitor
- ☐ Study navigation where images can be paged through with keyboard/mouse
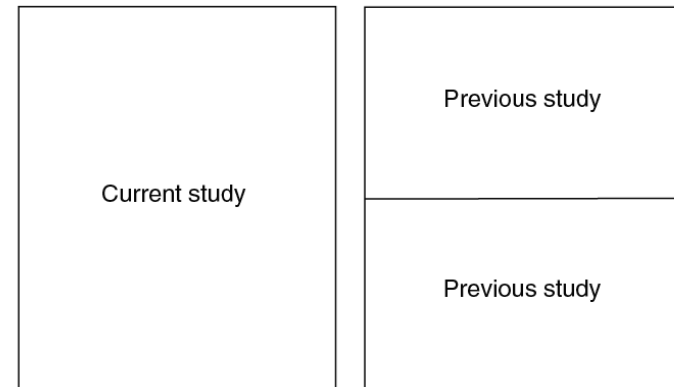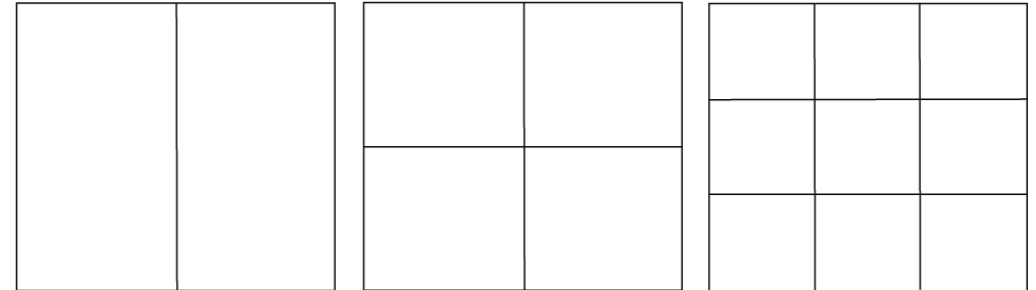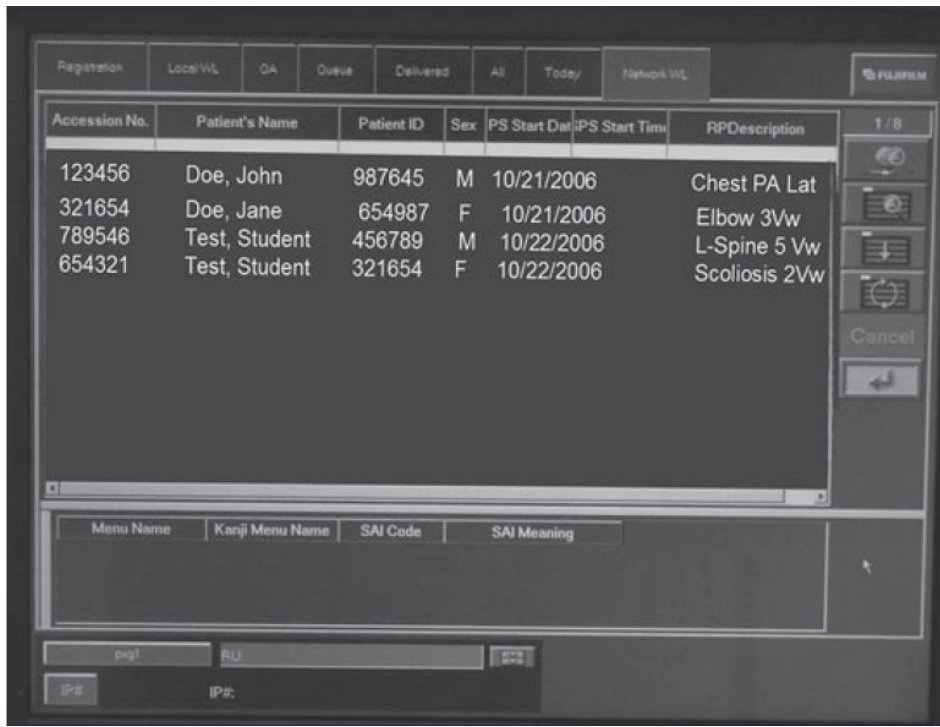
Common PACS Workstation Functions

- Image Manipulation and Enhancement Functions
  - Window/level
  - Annotations
  - Flip/rotate
  - Pan, zoom, and magnify
  - Measurements
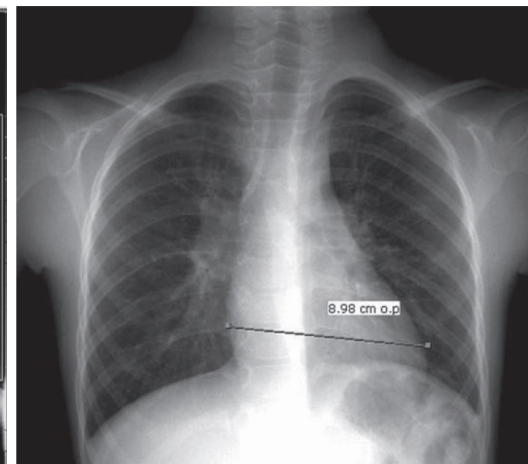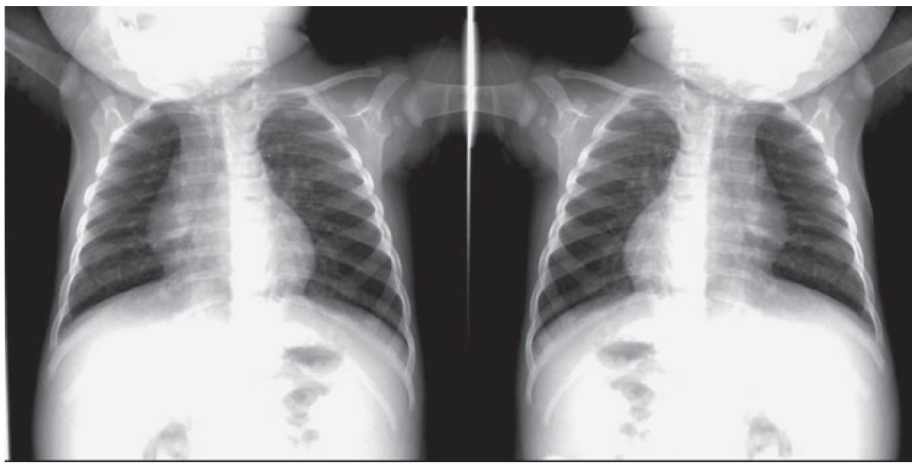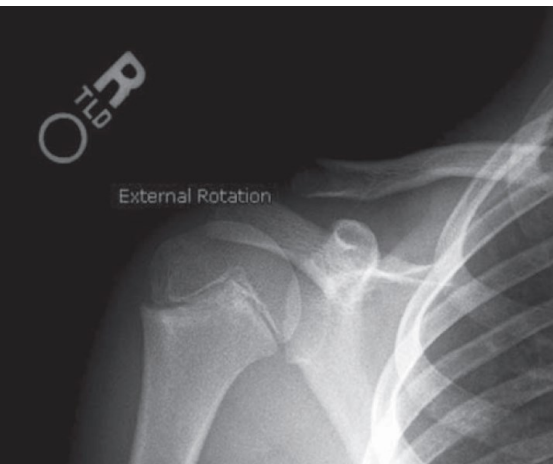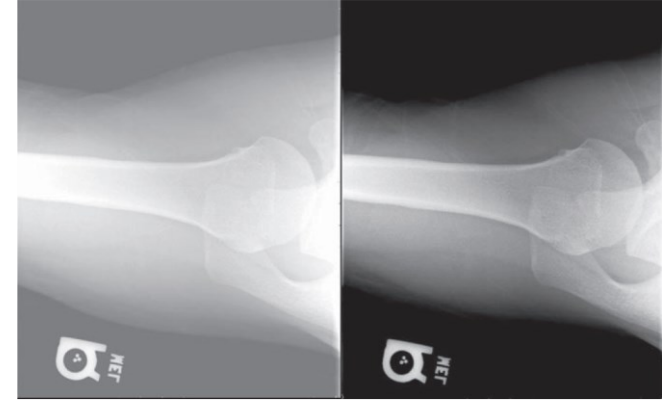
Common PACS Workstation Functions

□ Image Management Functions

  ◻ Modification of patient demographics

  ◻ Query/retrieve study

  ◻ CD-burning option

  ◻ Copy/paste image into document

  ◻ Print film
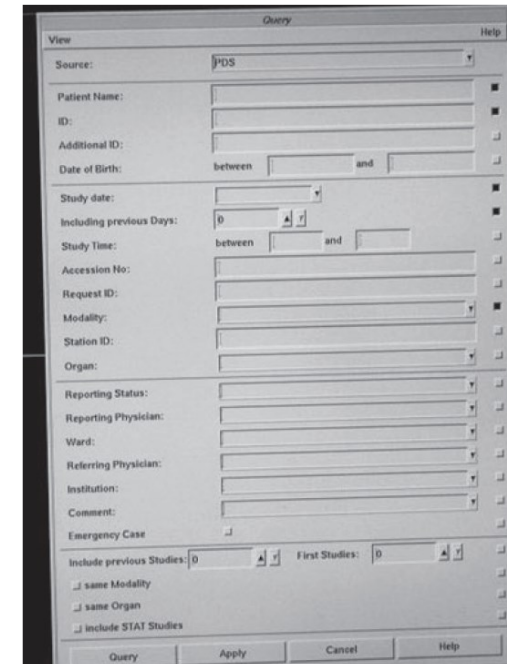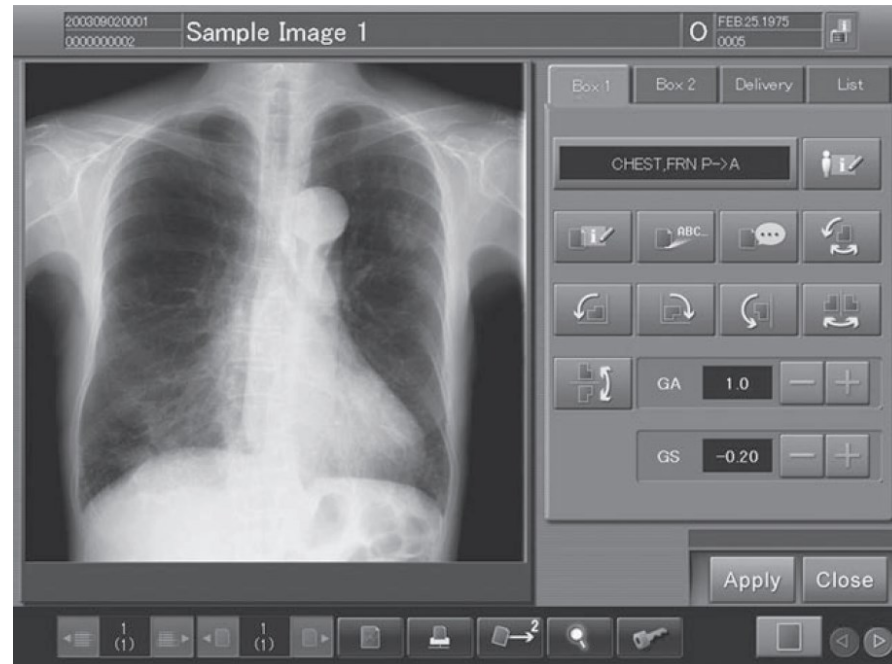
Common PACS Workstation Functions

- Advanced workstation functions
  - Reading station advanced functions
    - Multiplanar Reconstruction (MPR)
    - Maximum Intensity Projection (MIP)
    - Volume Reconstruction Technique (VRT)
    - Shaded Surface Display (SSD)
  - Technologist QC station advanced functions
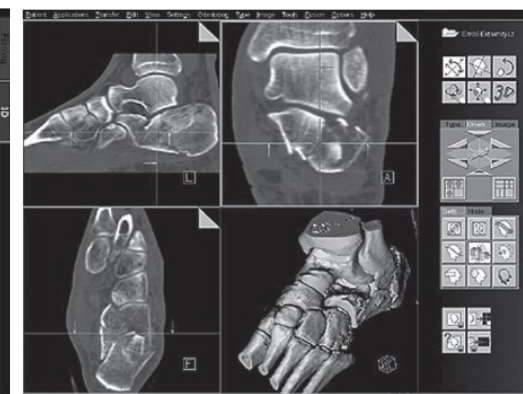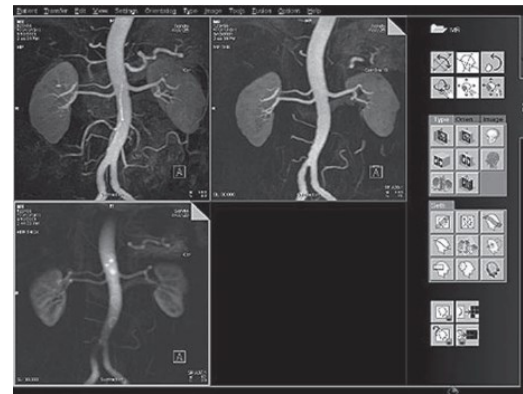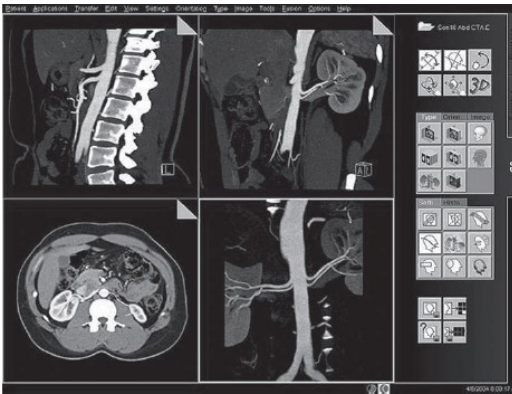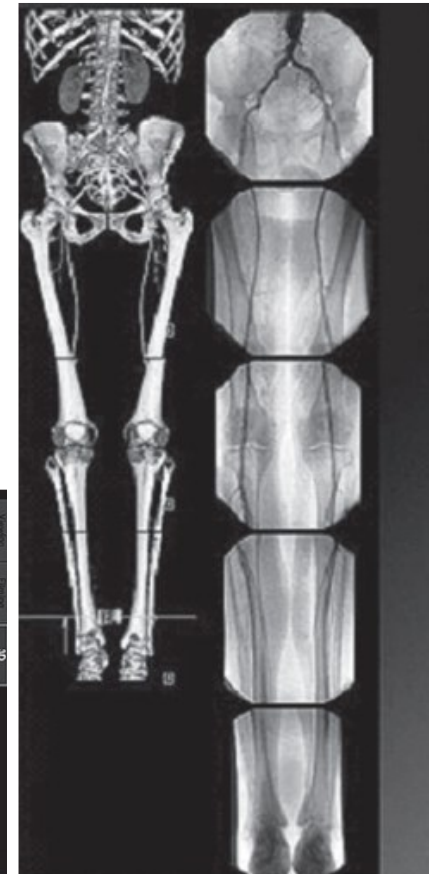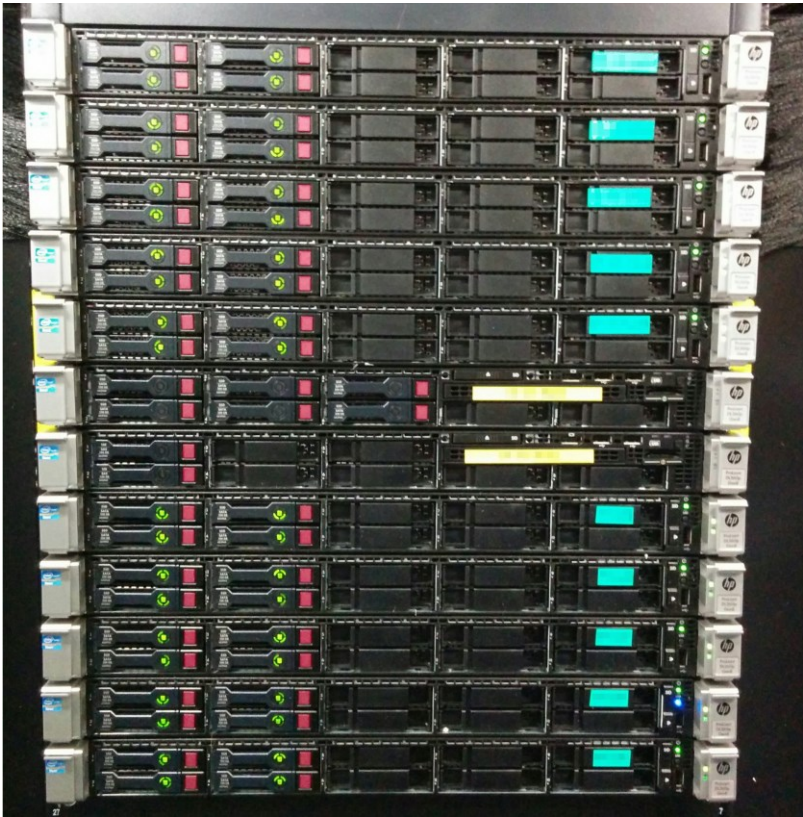   - Stitching of multiple images into one
    - Image postprocessing

Image Manager

□ Master database of everything that is in archive

  ▫ Controls receipt, retrieval, and distribution of images it stores and also controls all the DICOM processes running within the archive

□ Implemented using reliable commercial database with structured query language (SQL) and contains only image header information not image data

  ▫ Image data are stored on archive server

□ Database is mirrored where two identical databases running simultaneously

  ▫ If one goes down, system can call on mirror and continue to run as normal (very important feature)

□ Interface with radiology information system (RIS) and hospital information system (HIS)

  ▫ Retrieve patient information

  ▫ Populate EHR of patient

Image Storage on Archive Server

- ☐ Short-Term Storage
  - ❏ Redundant array of independent (inexpensive) disks (RAID) for reliability and fault tolerance
    - ■ Striping, mirroring, error correction

| RAID LEVEL	METHOD	HARDWARE / SOFTWARE	MINIMUM # OF DISKS	COMMON USAGE	PROS	CONS
JBOD	SPANNING		2	INCREASE CAPACITY	COST-EFFECTIVE STORAGE	NO PERFORMANCE OR SECURITY BENEFITS
0	STRIPING		2	HEAVY READ OPERATIONS	HIGH PERFORMANCE (SPEED)	DATA IS LOST IF ONE DISK FAILS
1	MIRRORING		2	STANDARD APP SERVERS	FAULT TOLERANCE, HIGH READ PERFORMANCE	LAG FOR WRITE OPS, REDUCED STORAGE (BY 1/2)
5	STRIPING & PARITY		3	NORMAL FILE STORAGE & APP SERVERS	SPEED + FAULT TOLERANCE	LAG FOR WRITE OPS, REDUCED STORAGE (BY 1/3)
6	STRIPING & DOUBLE PARITY		4	LARGE FILE STORAGE & APP SERVERS	EXTRA LEVEL OF REDUNDANCY, HIGH READ PERFORMANCE	LOW WRITE PERFORMANCE, REDUCED STORAGE (BY 2/5)
10 (1+0)	STRIPING & MIRRORING		4	HIGHLY UTILIZED DATABASE SERVERS	WRITE PERFORMANCE + STRONG FAULT TOLERANCE	REDUCED STORAGE (1/2), LIMITED SCALABILITY

Image Storage on Archive Server

- Long-Term Storage
  - Many hospitals use cost-effective RAID storage for both their short-term and their long-term archive
  - Other long-term storage products that are still widely used include tape and magneto-optical disk (MOD)
    - Usually jukebox is used for storage control, organization and interface with image manager
  - Long-term archive has much higher access times than short-term archive, but price per gigabyte is much less
- Application Service Provider (ASP): outsourcing of archiving and management functions for pay-per-use or pay-per-month charge
  - Useful as disaster recovery mechanism that keeps complete copy of archive in another location whereby it is immediately available if front-line archive goes down


Fermi National Accelerator Laboratory
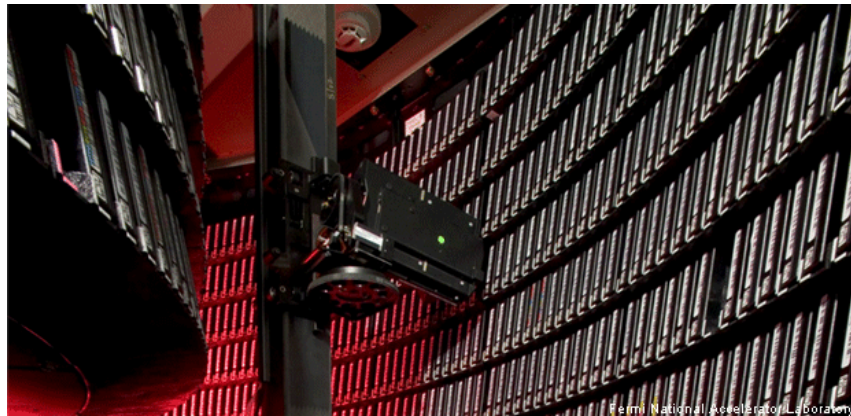
PACS Peripheral Devices: Film Digitizers

☐ Scan analog films to produce digital images using laser or charge-coupled device (CCD) technologies

☐ Used for teleradiology, storing film studies from outside to PACS, film duplication
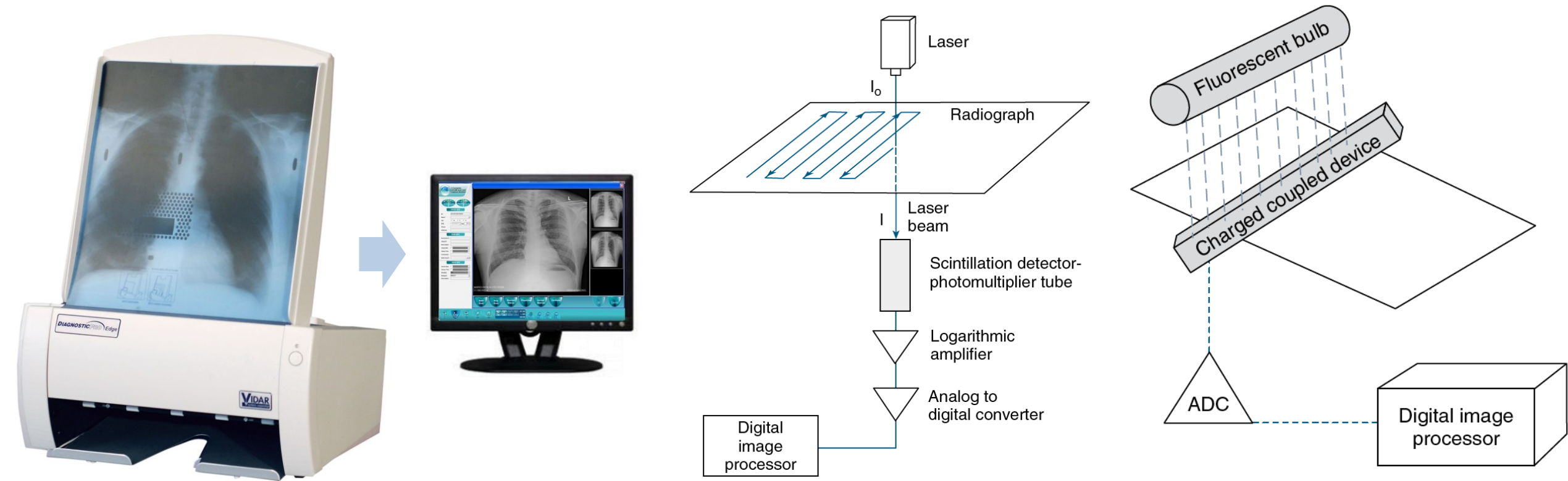
PACS Peripheral Devices: Film Printers (Imagers)

- Receive image from workstation and print image on film using one of two technologies
  - Wet imagers use chemicals to process the film that has been exposed to laser
  - Dry imagers use heat to process latent image etched into silver emulsion by laser
- Wet imagers must be placed in well-ventilated area with proper drainage and plumbing and also take up much more space than dry imagers
  - Also cost of chemicals, disposal, and maintenance make them less popular choice than dry imagers
- Dry imagers have slightly worse quality than wet imagers, and film quality tends to degrade over time, and more sensitive to heat and humidity than conventional film
  - Major advantage: dry imager only requires outlet and network connection
- Used as backup in case PACS is down
  - Also for cases referred by outside physician
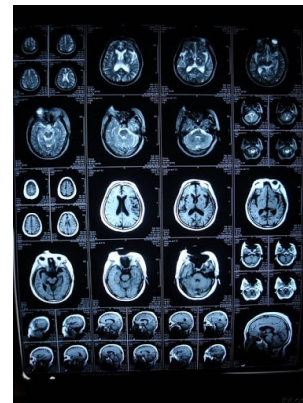
PACS Peripheral Devices: CD/DVD Burner

- Film printing is costly part of PACS
  - Laser film is expensive than and most hospitals try to reduce the amount of printing done
  - One alternative to printing hard copies is to burn images to optical disk
- PACS vendors offer ability to burn images to CD/DVD for purpose of sharing images outside of PACS
  - DICOM viewer is burned on disk to display images and basic enhancements and measurements
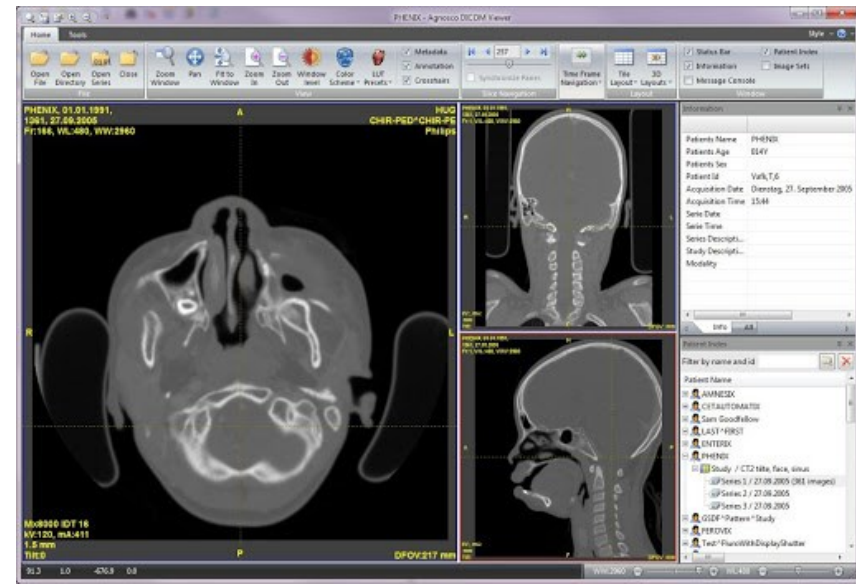
Reference Material

- Christi E. Carter, Beth L. Vealé, *Digital Radiology and PACS*, Mosby, 2010.
    - Chapters 8, 9, 10