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RADIOLOGY APPLICATIONS IN TELEMEDICINE

J. Anthony Seibert, Ph.D.
Professor of Radiology
University of California Davis Health System

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HEALTH SYSTEM

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DIGITAL IMAGING IN RADIOLOGY

- *Digital* imaging is an *essential* component of telemedicine and remote diagnosis
- Steps for digital imaging
 - Acquisition
 - Display
 - Diagnosis
 - Distribution
 - Archive

WHY DIGITAL?

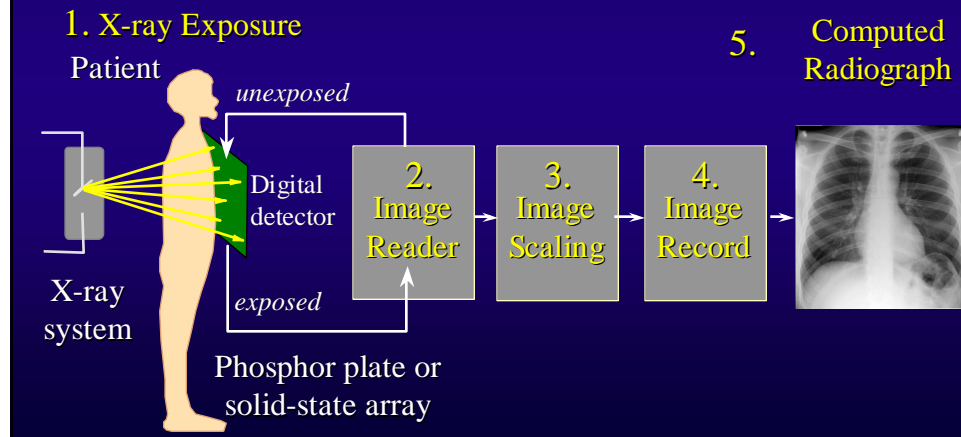
- Flexibility in acquisition and display
- Digital storage *and* retrieval
- Distribution of multiple *exact* copies
- Efficiency gains in image handling / storage
- Quantitative data extraction / assisted diagnosis
- Remote diagnosis – telemedicine / teleradiology

DIGITAL IMAGING MODALITIES IN RADIOLOGY

- Computed & Direct Radiography (CR / DR)
- Digital Subtraction Angiography (DSA)
- Computed Tomography (CT)
- Ultrasound (US)
- Magnetic Resonance Imaging (MRI)
- Nuclear Medicine (NM)

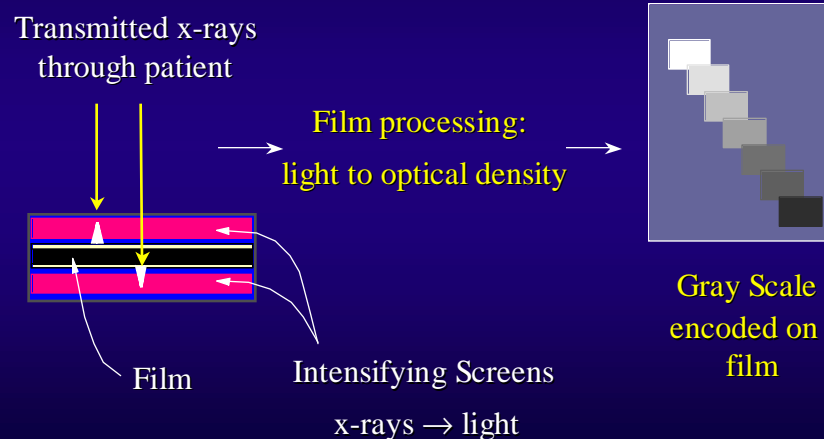
CR & DR

- Plain film represents 60-70% of image volume
- *Digital* capture of projection images is essential

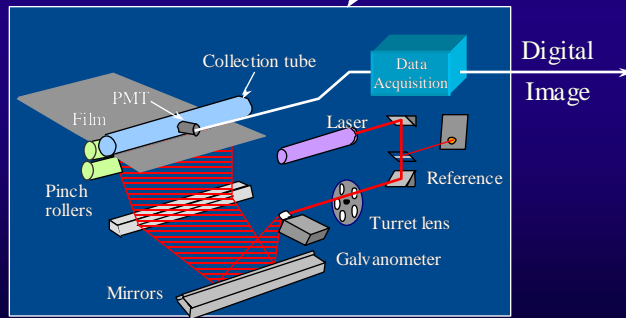
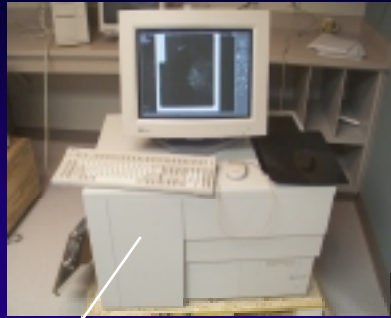


CONVENTIONAL SCREEN/FILM DETECTOR

1. Acquisition, Display, Archiving: A SIMULTANEOUS process

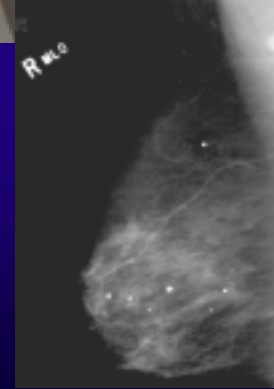


FILM DIGITIZER: Convert analog to digital signal



Laser beam transmission determined by film OD

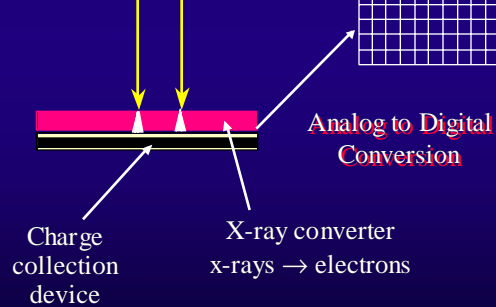
Digital
Image



DIGITAL X-RAY DETECTOR

1. Acquisition

Transmitted x-rays
through patient



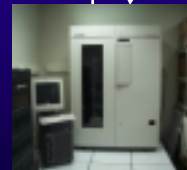
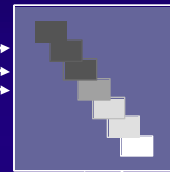
Analog to Digital
Conversion

Digital Pixel
Matrix

Digital
processing

2. Display

Digital to Analog
Conversion



SEPARATE processes that allow
image manipulation and enhancement

3. Archiving

DIRECT ACQUISITION OF DIGITAL DATA: COMPUTED RADIOGRAPHY

CR
Reader



Film laser printer



RIS
PACS
DICOM

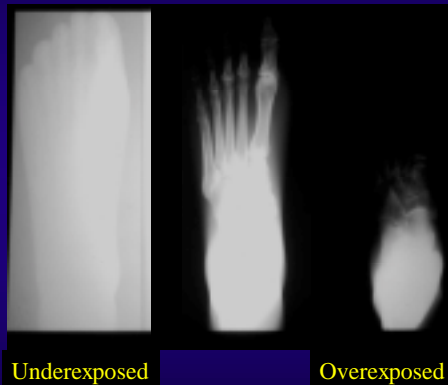


CR - QC Workstation

Soft-copy review

ANALOG VERSUS DIGITAL COMPARISON

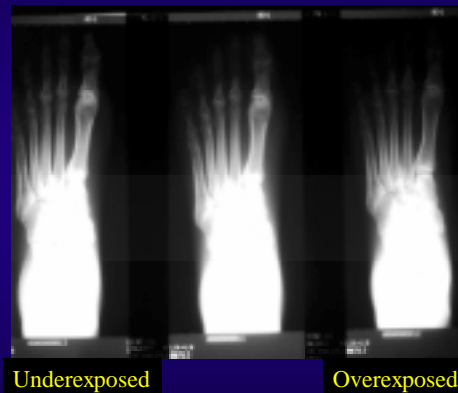
Screen-Film



Underexposed

Overexposed

Computed Radiography



Underexposed

Overexposed

Digital acquisition tolerance of inappropriate exposures

Screen-Film

80 kVp, 18 mAs



400 speed screen - film

CR

80 kVp, 64 mAs



80 kVp, 18 mAs

Digital wide latitude

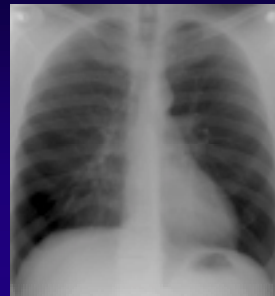
Digital acquisition Image processing and display flexibility

CONTRAST AND EDGE ENHANCEMENT

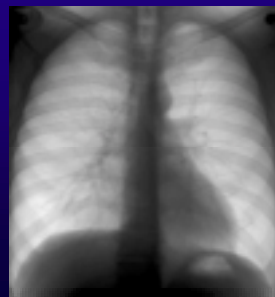
Raw



Contrast
Enhanced



“Black
Bone”



Edge
Enhanced



DUAL ENERGY RADIOGRAPHY

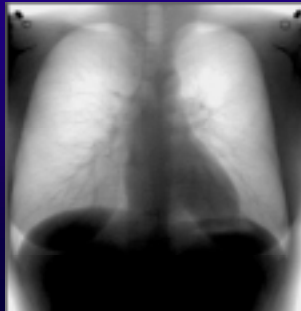
Low
Energy



High
Energy



Soft
Tissue



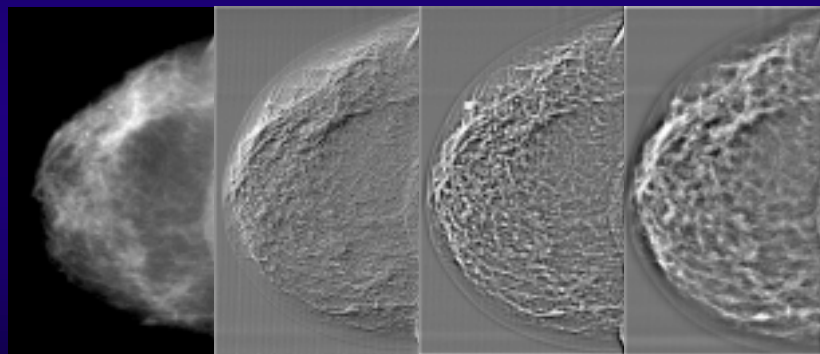
Calcium
& Bone



IMAGE PROCESSING

Original

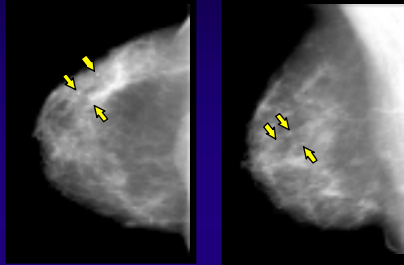
High Pass Filter
(k=5) (k=15) (k=35)



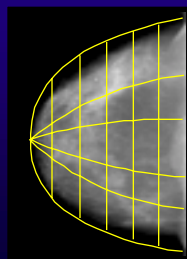
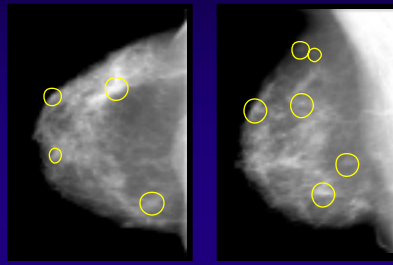
Processing enhances and reduces image
attributes for improved diagnostic capabilities

COMPUTER AIDED DIAGNOSIS

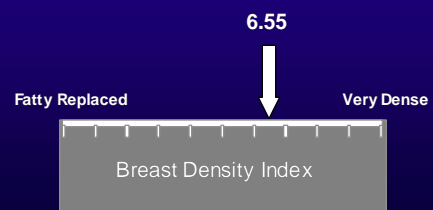
Identification of Suspected Microcalcifications



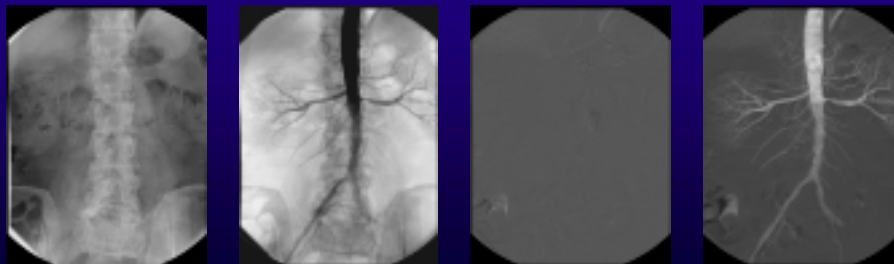
Identification of Suspected Masses

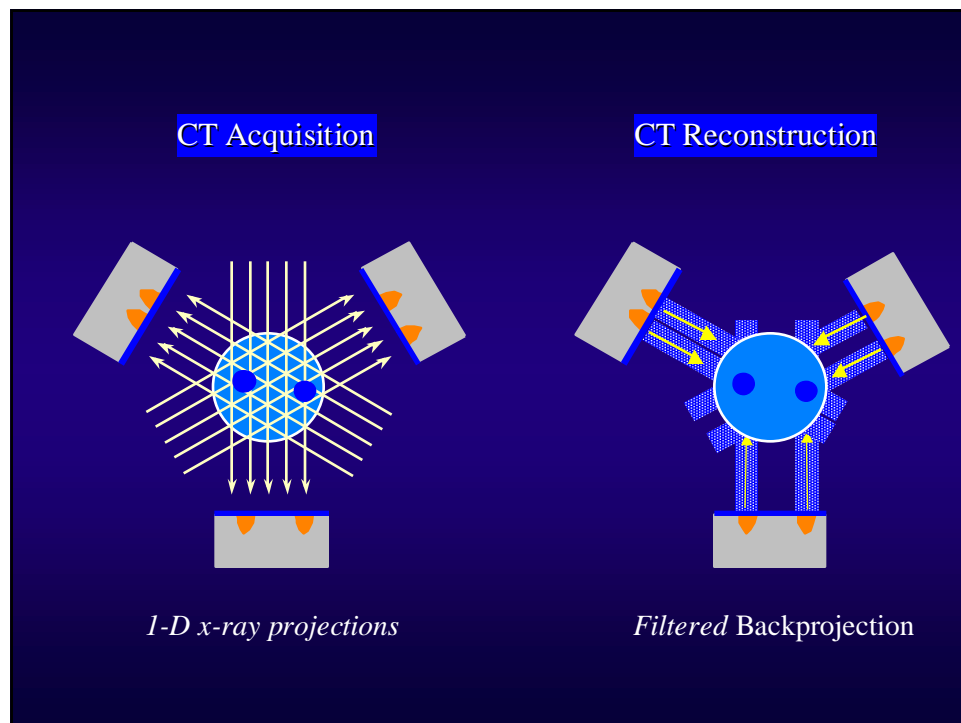
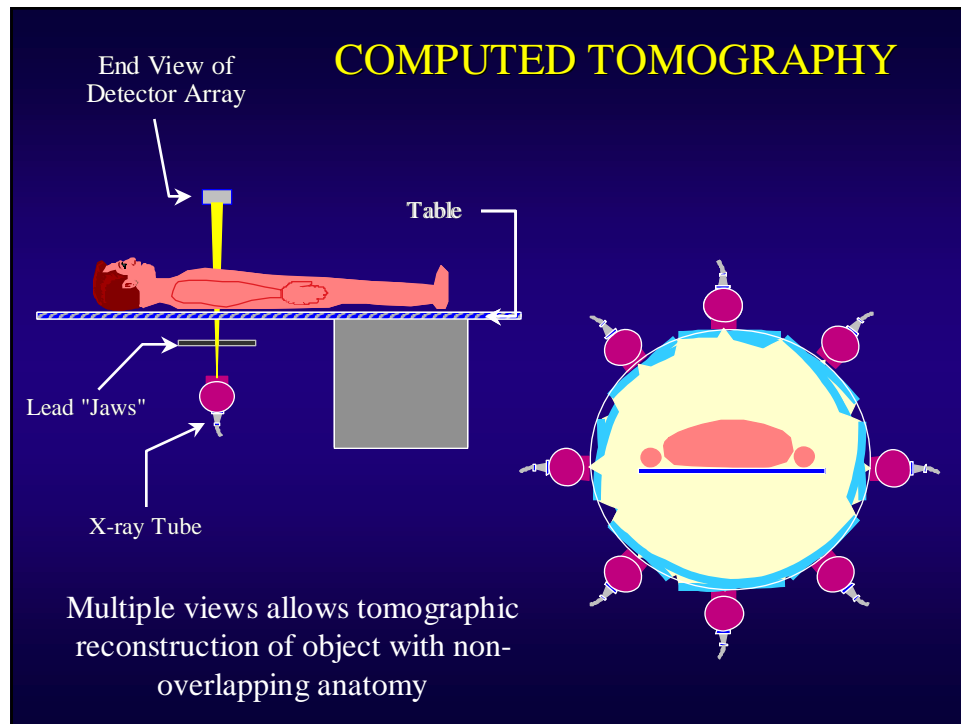


Quantification of Breast Density



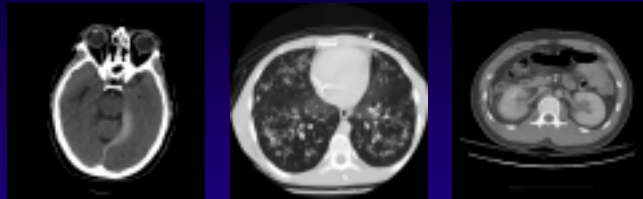
DIGITAL SUBTRACTION ANGIOGRAPHY



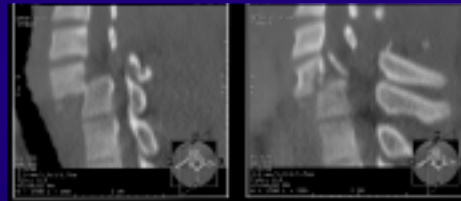


COMPUTED TOMOGRAPHY EXAMPLE IMAGES

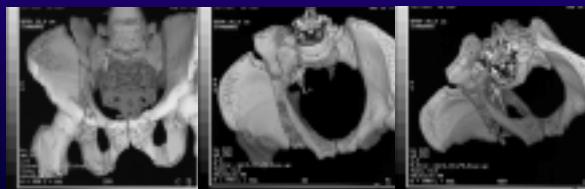
Axial
images



Multiplanar
reconstruction



3D
surface
display



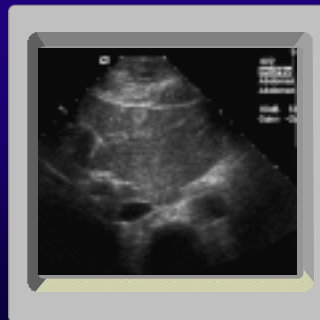
ULTRASOUND (Sonography)

Send and Receive mechanical energy via
piezoelectric crystal (transducer)

Echoes are produced from acoustic
property differences of the tissues

Pulse →

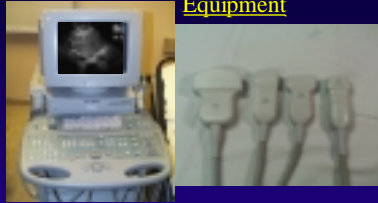
← Echo



Provides an “acoustical map” of
the tissues
mechanical, non-ionizing energy

ULTRASOUND

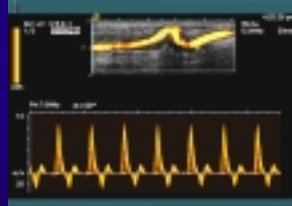
Equipment



2D cross-sectional



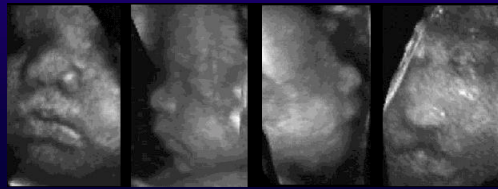
Doppler



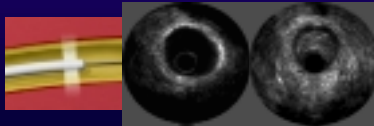
Conventional

Harmonic

3D



Intravascular



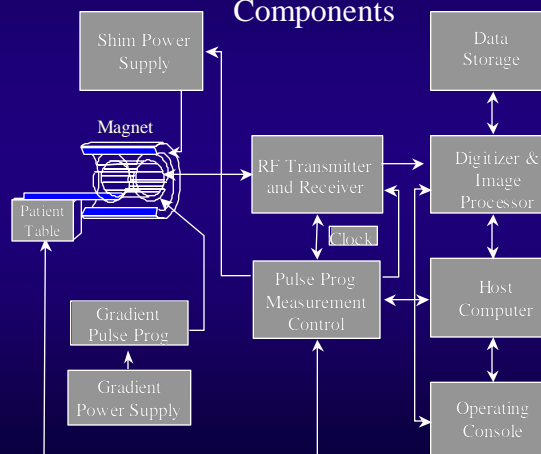
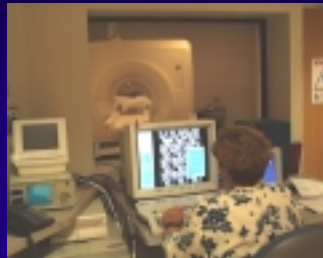
MAGNETIC RESONANCE IMAGING

MRI Equipment

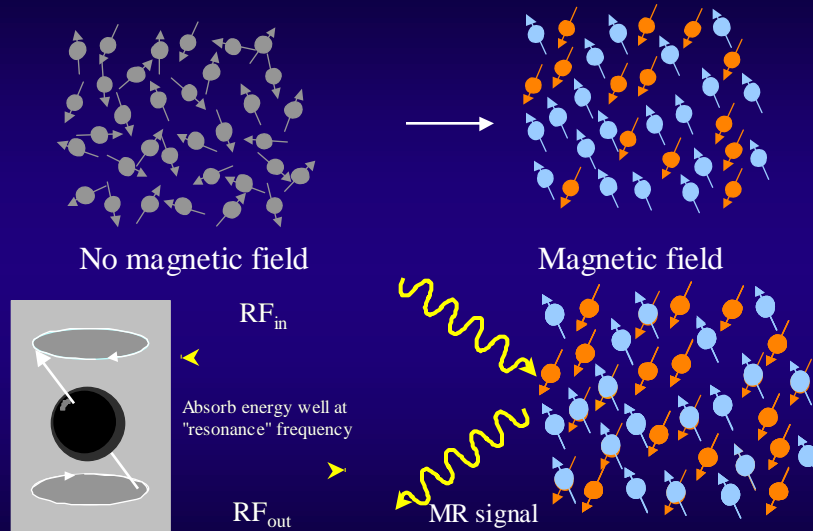
Magnet

0.3 - 1.5 Tesla ($\sim 30,000 \times$ earth's field)

Components



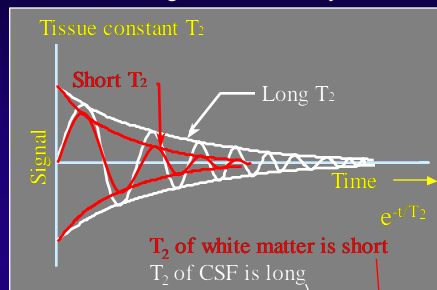
MRI: provides a tomographic map of the magnetic properties of protons in tissues



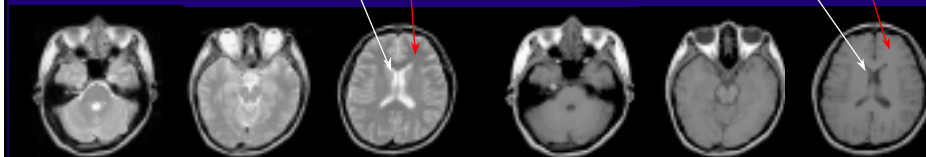
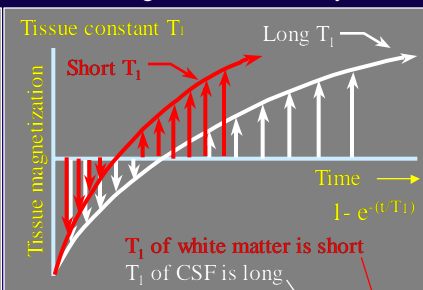
Precession at specific frequency allows selective excitation of protons and emission of tissue-specific signals

MRI: CONTRAST MECHANISMS

Magnetization Decay



Magnetization Recovery



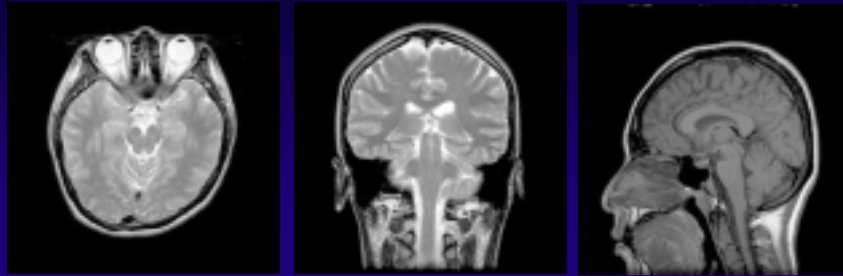
TR:3550 TE:87.6

"T2 contrast" weighting

TR:467 TE:8.0

"T1 contrast" weighting

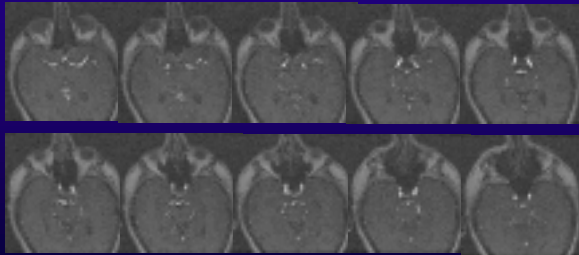
MRI: DIRECT MULTI-PLANAR ACQUISITION



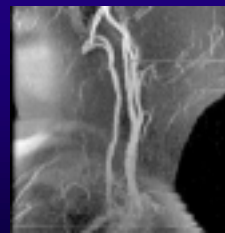
Axial

Coronal

Sagittal



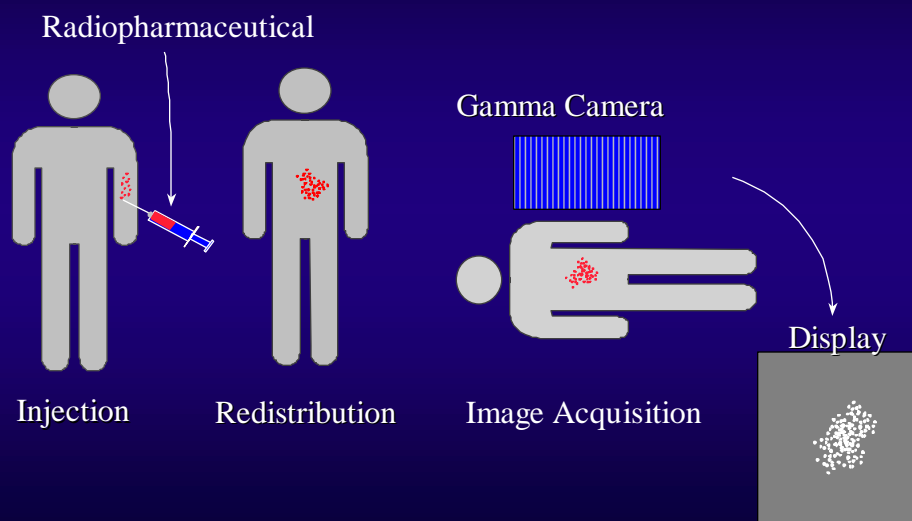
TOF Images

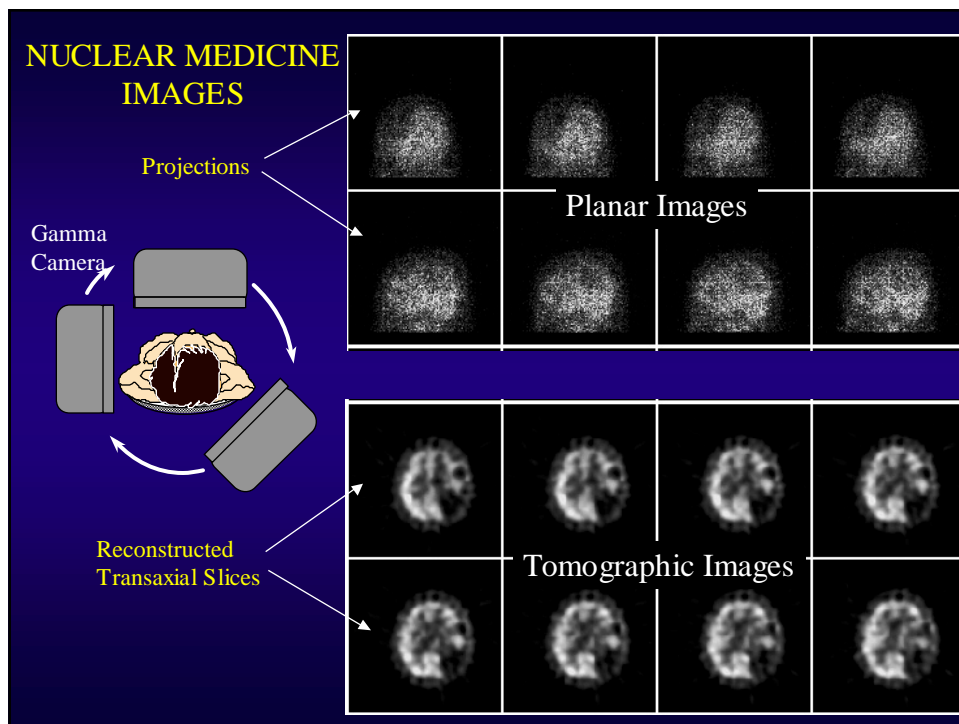


MR ANGIOGRAPHY

NUCLEAR MEDICINE

Metabolic AND molecular imaging





MEDICAL IMAGING MODALITIES

- Common thread
 - Digital data (and lots of it!!)
- Problems
 - Proprietary structures
 - Unknown data format
- Solutions
 - DICOM and PACS
 - HL-7 and RIS
 - Networking and Informatics

TERMINOLOGY

- **RIS**
 - Radiology Information System
 - Transcription, Reporting, Ordering, Scheduling, Billing
- **PACS**
 - Picture Archiving and Communication System
 - Acquisition, Interpretation, Storage
- **Integrated Medical Imaging**
 - RIS, PACS
 - Everything Else!

Everything Else!

- **RIS-PACS Integration**
 - Data Synchronization, Validation
 - Interpretation & Results Reporting
- **New Opportunities**
 - Value Added, Patientless Examination
 - Computer Aided Diagnosis
- **Image Distribution (The Internet)**
 - Clinical Review, OR, Patients, Conferences
 - Enterprise Integration - EMR
 - Teleradiology

COMMUNICATION PROTOCOLS

- **TCP/IP**
 - Standard Communications Protocol
 - The Internet
- **HL-7**
 - Health Level 7
 - RIS / HIS
- **DICOM 3.0**
 - Digital Imaging COmmunications in Medicine v3.0
 - PACS
- **HTTP**
 - Hyper-Text Transport Protocol
 - The World Wide Web

COMMUNICATION PROTOCOLS

THE INTERNET

TCP/IP

HL-7

DICOM

HTTP

IMAGE COMPRESSION

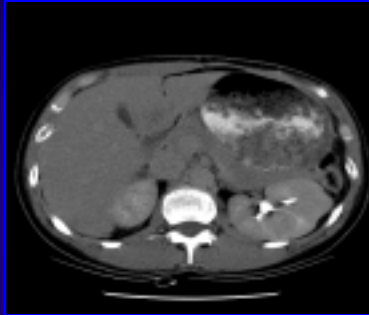
- 1 bit = a light switch, **ON or OFF, 0 or 1** (2 Values)
- 1 byte = 8 bits '0000'0000' to '1111'1111' (256 Values)
- 1 Kilobyte (KB) = 1,000 bytes
- 1 Megabyte (MB) = 1,000 KB
- 1 Gigabyte (GB) = 1,000 MB
- 1 Terabyte (TB) = 1,000 GB
- 1 Pedibyte (PB) = 1,000 TB
- **Average Radiology Exam is ~ 20MB**
- 280,000 Exams = ~ **5.6 Terabytes / year**
@ UCDMC Radiology



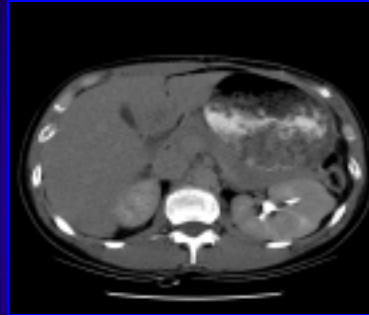
IMAGE COMPRESSION

- Average Radiology Exam is ~ 20MB
- Lossless Compression - JPEG
 - ~ 2:1 > 10MB Xfer
- Lossy Compression - Wavelet
 - ~ 20:1 > 1MB Xfer
- JPEG 2000
 - Combines Lossless techniques and Lossy Wavelet
 - Finally standards based Wavelet compression
 - DICOM approval of advanced compression by 2000?

IMAGE COMPRESSION



Original
500 Kbytes



12:1 Wavelet
42 Kbytes

Compression allows more efficient use of limited bandwidth
(e.g., telephone modems)

IMAGE COMPRESSION

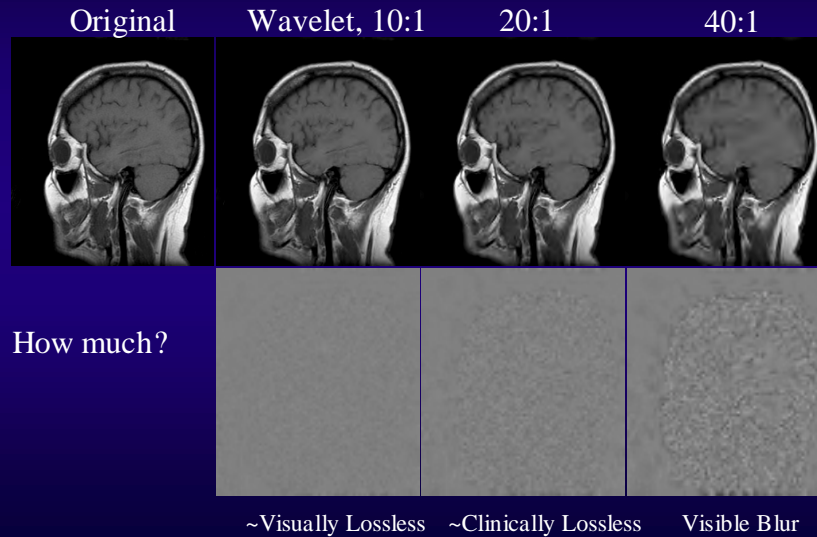


Original
8000 KBytes



35:1 Wavelet
230 KBytes

IMAGE COMPRESSION: HOW MUCH?

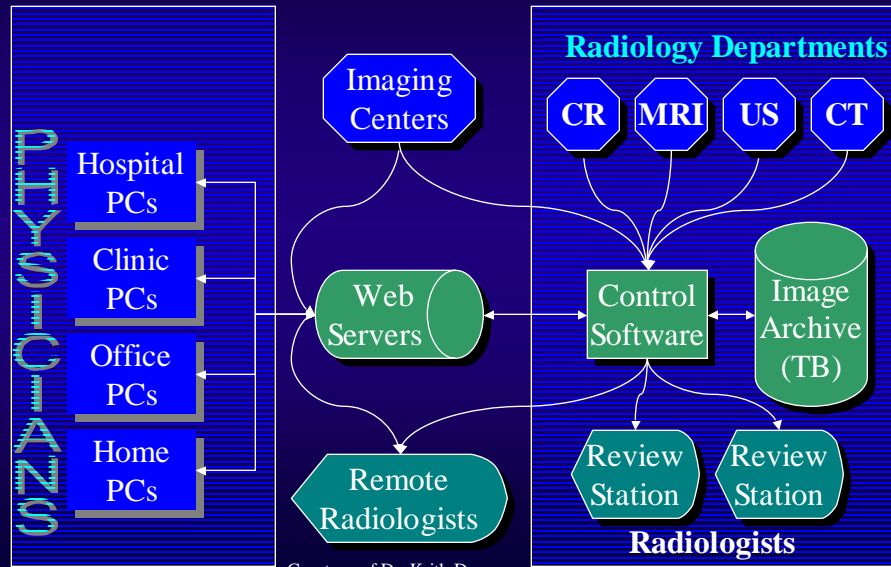


Tolerance to Compression Based on Type of Image

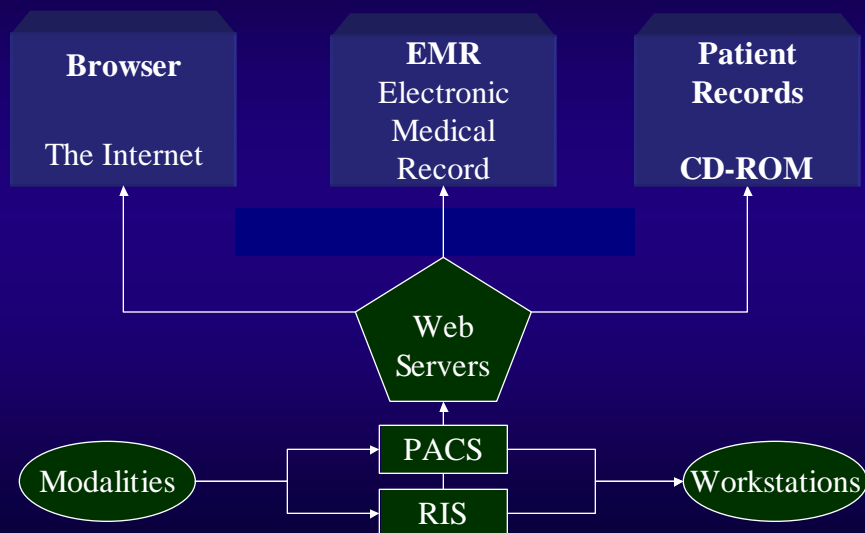


Courtesy of Nicholas Hangiandreou, Mayo Clinic, Rochester, MN

IMAGE DISTRIBUTION: Web and the Internet



CLINICAL DISPLAY

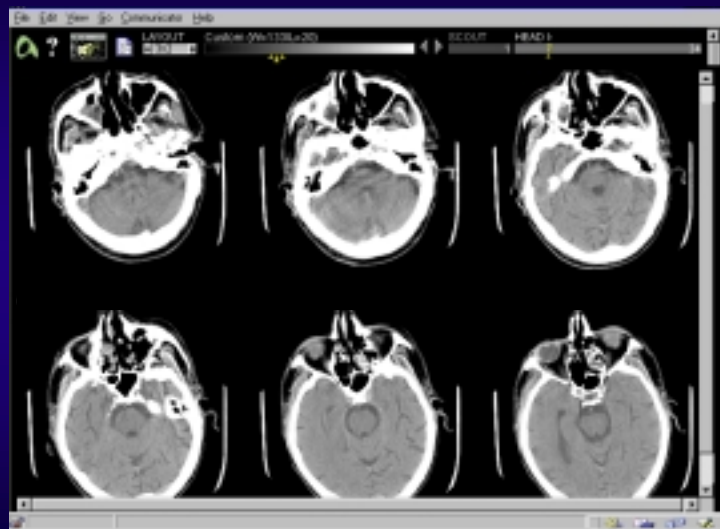


BROWSER DISPLAY

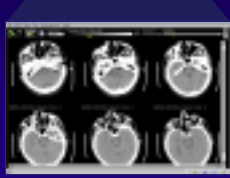
The screenshot displays the STENTOR web application interface. The top section shows a patient list with columns for Case #, Patient Name, Patient ID, Study Date, and Patient Location. Below this, a detailed view of a patient's scan is shown, including a 3D head scout and two axial CT slices. The patient information at the top of the detailed view includes: PATIENT LAST, FIRST 1; Sex: F; BirthDate: 10/10/1951; Patient ID: 0000000; and Patient 1. The scan information at the bottom of the detailed view includes: HEAD; Head Type: Fast Scan; Scan #: 1234; and Head 1.

Case #	Patient Name	Patient ID	Study Date	Patient Location
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	
+	PATIENT, NAME	0000000	09/25/2000-00:00:00	

BROWSER DISPLAY



Courtesy of Dr. Keith Dreyer



EMR
Electronic
Medical
Record

Patient
Records
CD-ROM

Courtesy of Dr. Keith Dreyer

The screenshot displays the 'Clinical Application Suite' interface. At the top, a status bar indicates the user is logged in as 'Keith J. Draper' on 'Tuesday, Sep 8, 1998'. Below this, a navigation bar includes a 'Select' dropdown, a search field, and buttons for 'MICROBIOLOGY', 'MEDICAL A/B CLABS', and 'PD Default'. The main content area is divided into several sections: 'Microbiology' (with sub-sections 'Big Band' and 'Labs'), 'Blood Bank', 'Reports' (with 'Clinical Summary'), and 'List Known Values'. A sidebar on the left contains buttons for 'Results', 'List signs', 'BIO', 'Feedback', and 'Exit'. The central part of the screen features a table with columns for 'Patient Name', 'Location', 'CHW', 'HEM', 'MR', 'MC', 'EKG', 'RAD', 'PAT', 'CAR', 'OPR', 'DIS', 'END', and 'PUL'. The table contains several rows of patient data, with some cells highlighted in yellow. At the bottom, there is a 'Show Selected Patient Only' checkbox, a 'Show Selected Patient List (Eligible 4 SCL)' checkbox, and a 'Refresh' button. The bottom status bar shows 'CWS 4.0b', 'Start', 'Clinical Application Suite', 'nc2bmg - Print', and system icons including a clock showing '11:59'.

Patient Name	Location	CHW	HEM	MR	MC	EKG	RAD	PAT	CAR	OPR	DIS	END	PUL
888818A	4 ml	5 hr			5 hr	3 dy	1 hr	39 dy	47 dy	14 dy	2 yr		
888832A	44 ml	4 hr			7 hr	4 hr	20 hr		3 hr		8 mo		
888838A	50 ml	2 hr			7 hr	3 hr	15 dy	3 hr	3 hr		15 dy		
888839A	43 ml	4 hr			6 hr	4 hr	10 hr		8 hr		16 dy		
888840A	3 ml	15 hr			6 hr	40 hr	5 hr		3 hr	8 hr			
888843A	18 ml	4 hr			4 hr	3 dy	8 hr	8 hr	61 hr	11 dy			
888843B	5 hr	19 hr			5 hr	3 dy	8 hr		95 hr	4 dy	8 mo	10 dy	

Courtesy of Dr. Keith Dreyer

ELECTRONIC MEDICAL RECORD

The screenshot displays the 'Clinical Application Suite' window for a patient named 'KORNG, IDY F'. The interface includes a sidebar with navigation options like 'Results', 'List Mgmt', 'Info', 'Feedback', and 'Exit'. The main content area is titled 'Index: Clinical Summary' and lists various medical procedures and their dates. A table of radiology results is shown below the index.

Procedure	Date	Accession#	Status
Chest, 1 view	05-Sep-1998	04:00	Accession# 4977788 Prelim
Chest, 1 view	04-Sep-1998	05:29	Accession# 4976226 Prelim
AbdCT + PelCT +	03-Sep-1998	22:45	Accession# 4975741 Final
CT THORAX W/CON	03-Sep-1998	22:45	Accession# 4975742 Prelim
CT HEAD W/O CON	03-Sep-1998	21:39	Accession# 4975836 Final
Chest, 1 view	03-Sep-1998	05:28	Accession# 4974811 Final
Chest, 1 view	02-Sep-1998	22:45	Accession# 4973978 Final
Chest, 1 view	01-Sep-1998	05:35	Accession# 4973183 Final

Below the table, the 'Details' section contains a 'HISTORY' and a 'REPORT'. The 'REPORT' section describes a CT scan of the thorax, noting the presence of an endotracheal tube, a left IJ CVP catheter, and a nasogastric tube. It also mentions a large pericardial collection.

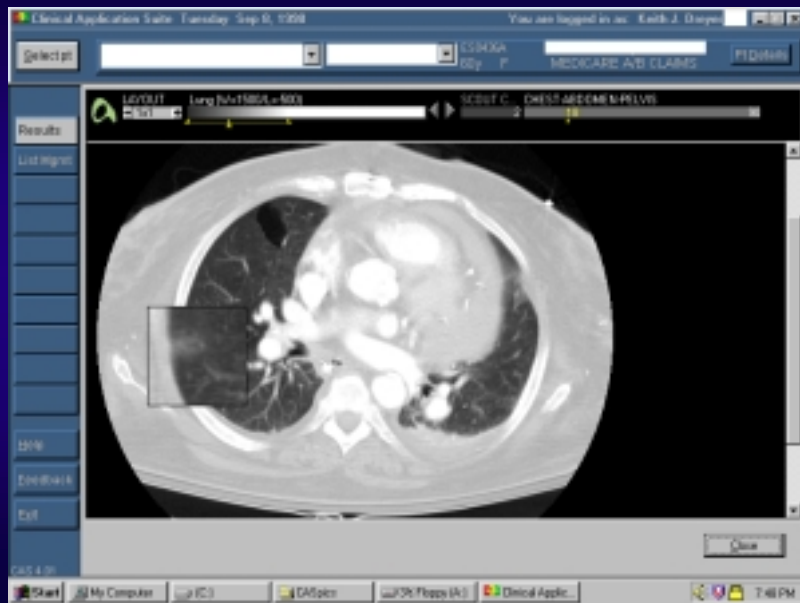
Courtesy of Dr. Keith Dreyer

ELECTRONIC MEDICAL RECORD

The screenshot displays the 'Clinical Application Suite' window for a patient named 'KORNG, IDY F'. The interface includes a sidebar with navigation options like 'Results', 'List Mgmt', 'Info', 'Feedback', and 'Exit'. The main content area shows a grid of radiology images, likely CT scans of the chest, arranged in two rows of five. The top row is labeled 'L20001' and the bottom row is labeled 'L20002'. The images are displayed in a grayscale format, typical of medical imaging software.

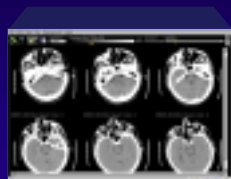
Courtesy of Dr. Keith Dreyer

ELECTRONIC MEDICAL RECORD



Courtesy of Dr. Keith Dreyer

CLINICAL DISPLAY

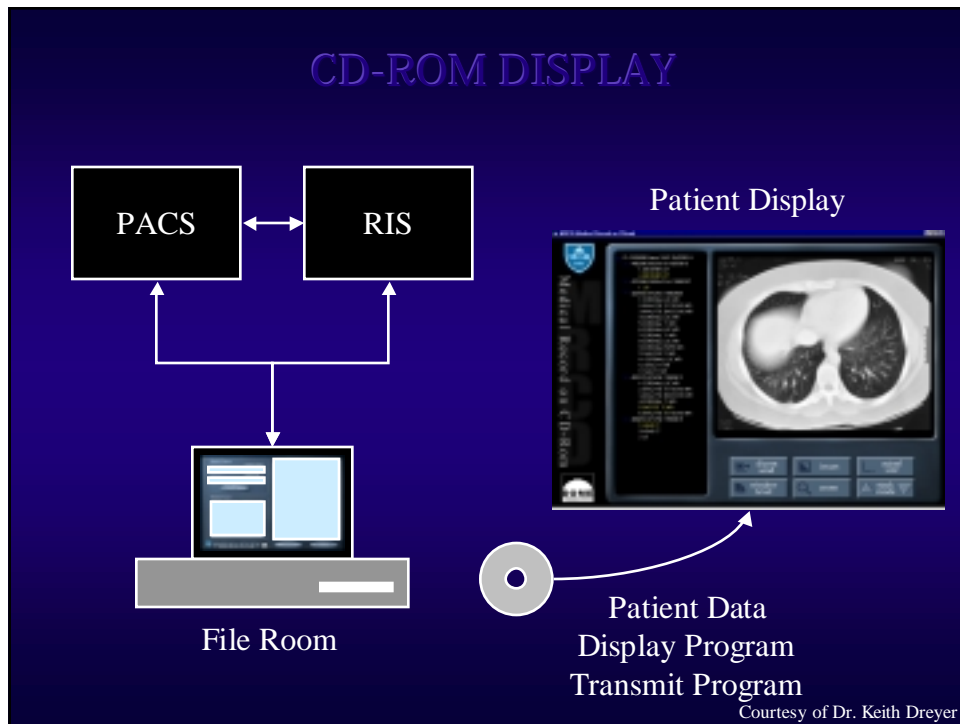


Patient
Records

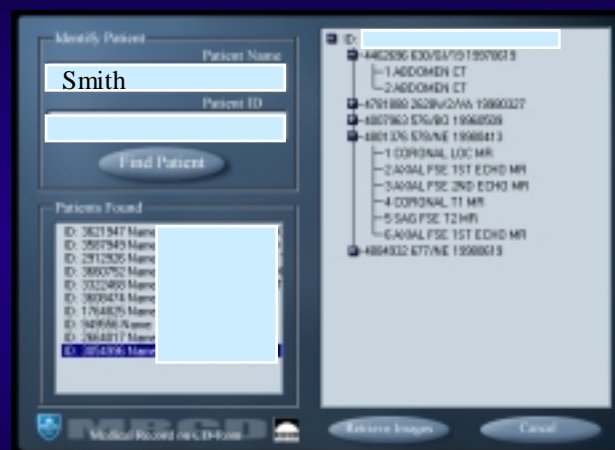
CD-ROM

Courtesy of Dr. Keith Dreyer

CD-ROM DISPLAY



CD-ROM DISPLAY



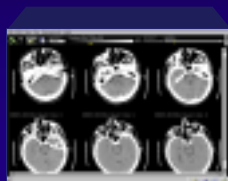
View of program on remote PC

Courtesy of Dr. Keith Dreyer



View of program on remote PC

Courtesy of Dr. Keith Dreyer



INTERNET

**EMR**

CD-ROM

Acknowledgment to Dr. Keith Dreyer
Massachusetts General Hospital
For clinical web-based information

SUMMARY

Enterprise distribution of images is crucial
for implementation and application of technology

- *Digital image acquisition, display, storage are a key to technological advances and improved delivery of medical services*
- A collective effort
 - Radiology and other users of images
 - Information Systems
 - Medical Informatics
 - Industry partnerships

SUMMARY

Enterprise distribution of images is crucial
for implementation and application of technology

- Telemedicine and teleradiology allow the exchange of technological ideas and implementation in a diverse number of associated fields
- The Internet solves many problems
- New opportunities abound
 - Image acquisition and image processing tools
 - Imaging technology innovation for diagnosis and intervention