# PACS

# Introduction

Picture
Archiving and
Communications
System

PACS

# Digital image acquisition, storage and transmission

PACS differs
from
film based radiography

# PACS affects

- Radiologists
- Radiological technologists
- Clinicians
- Nurses
- Hospital administrators
- Film filing personnel

The future of radiological imaging is

# PACS

And the future is

NOW

# PACS
# Part 1
# History

# In the beginning …

there were direct digital modalities:

CT, Ultrasound, Nuclear,
Magnetic Resonance

Which introduced people to the flexibility inherent in digital imaging - rapid access to images, manipulation of image contrast, etc.

Problems of early digital imaging:

Multiple vendors +
Proprietary systems
= Incompatibility

# Enter DICOM

Digital Imaging and Communications in Medicine

DICOM is based on the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) standard

# ACR-NEMA standard

- 1983 Established
- 1985 ACR-NEMA standard v1.0
- 1988 v2.0
- 1993 DICOM v3.0
- Continuous evolution

Ref 11

DICOM standardized communications protocols for image and image identification data so that equipment items from different vendors could communicate with each other.
It is a non-proprietary, open architecture standard.

# Open architecture - RADICAL CONCEPT!

Different pieces of equipment could communicate with each other, and could share the same patient demographic data from the hospital information system (HIS) or radiology information system (RIS),

- IF -

all the pieces of equipment were DICOM compatible.

# What catalyzed PACS?

- Increased number of studies ordered
- Increased number of images per study
- Increased use of personal computers

# Advantages of PACS

- Images can be manipulated to enhance diagnostic value
- No lost films
- No loss of resolution when images are copied

# More advantages …

- Simultaneous viewing
- Consultation at a distance
- Decreased repeat rate

# Still more advantages …

- Leveled workload
- Ability to annotate images
- Instant messaging

# Even still more advantages …

- Images can be stored on CD or DVD for the patient or physician
- Ease of conversion of images to multimedia teaching files

# PACS and the internet

Images can be transmitted to personal computers via the internet (using a secure connection) and can be accessed by physicians at their offices or homes

# Technical limitations of early PACS

- Computer equipment was expensive
- Computer memory was limited
- Storage memory was expensive and limited

# More limitations …

- Images files are large
- Transmission times were SLOW

# And still more limitations …

- High resolution monitors were expensive
- Limited image manipulation functions
- Not user friendly

# Administrative limitations

- No positive financial return for the institution
- What if we are the ‘only show in town’?
- Fear of obsolescence

# Enter …

- Less expensive computers and monitors
- Less expensive memory
- More user friendly software (GUI)
- More standardized controls (icons)

PACS becomes more feasible

The first institutions to install PACS were governmental institutions (military and Veterans Administration facilities)

Reliable source of funding

Relatively stable patient population

As hardware costs decreased and the advantages of PACS were realized and reported in the literature, PACS became a more realistic solution to the problem of increasing demand for radiological services.

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# PACS and the clinician

(What is means to you.)

# Advantages of PACS

- Images can be manipulated to enhance diagnostic value
- No lost films
- No loss of resolution when images are copied

- Simultaneous viewing
- Consultation at a distance
- Decreased repeat rate
- Leveled workload
- Ability to annotate images
- Instant messaging

- Images can be stored on CD or DVD and given to the patient or physician
- Ease of conversion of images to multimedia teaching files
- More rapid delivery of reports (Ref 5)

- Reports are included with the images
- Fewer interruptions of clinicians - 91% of physicians reported that they did not want to receive phone calls for routine results (Ref 7)

- Referring clinicians are able to review their images at times that are most convenient for them from within or from outside the facility via secure web based access

Ref 7

# Web access to images and reports

- Secure socket layer (SSL) guarantees integrity of data and confidentiality between client and server
- 128 bit encryption
- Ensures that the user has access only to data that he/she actually needs

Ref 9

- Reduced number of unreported cases after PACS installation (Ref 5)
- Time saved by clinicians after PACS installation ~ 30 minutes per day (Ref 5)

- 70% decrease in time for images to be available with PACS vs conventional film imaging (Ref 12)

Referring physicians prefer PACS over film with 91% reporting improved productivity with PACS

Ref 7

# Workstations

- High resolution monitors (‘standard’ is 2 megapixels, but can be up to 4 megapixels)
- Increased resolution --> increased cost
- 1, 2, 4 or 8 monitors?

# Workstation functions

- Change contrast
- Invert gray scale
- Flip
- Rotate
- Magnify

# Workstation functions cont'd …

- Pan
- Zoom
- Measure
  - Linear distance, area, angle, density

# Workstation functions cont'd …

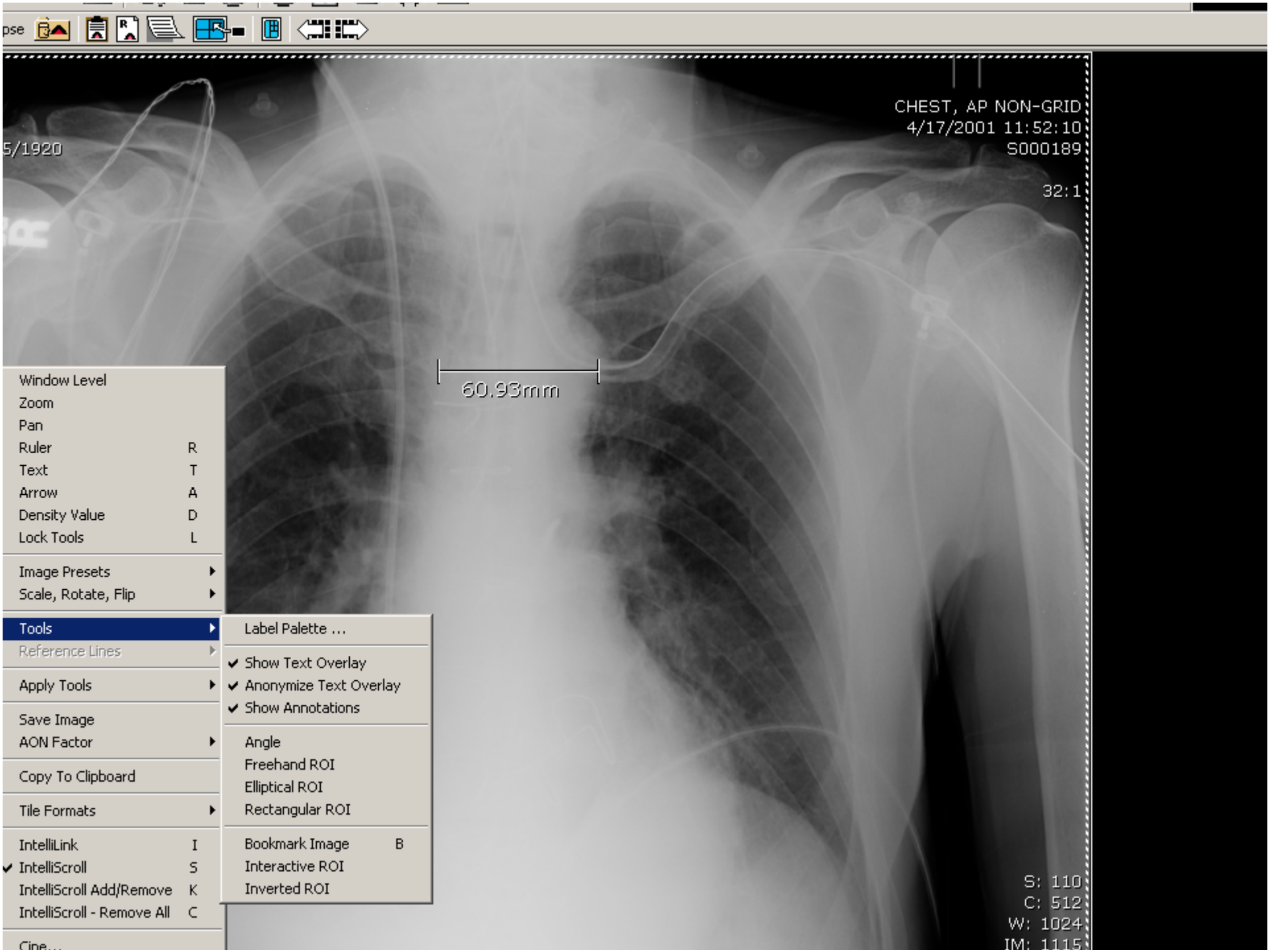
- Set individual preferences
- Choice of hanging protocols
- Automatic retrieval of comparison images

PACS screen images
provided courtesy of

FUJIFILM Medical Systems
USA, Inc.

With deepest appreciation to
Betty Assadullahi
FUJIFILM Medical Systems
USA, Inc.

Chest image with tool bar and pull down menus


5/1920
CHEST, AP NON-GRID
4/17/2001 11:52:10
S000189
32:1
60.93mm
Window Level
Zoom
Pan
Ruler R
Text T
Arrow A
Density Value D
Lock Tools L
Image Presets
Scale, Rotate, Flip
Tools
Reference Lines
Apply Tools
Save Image
AON Factor
Copy To Clipboard
Tile Formats
IntelliLink I
IntelliScroll S
IntelliScroll Add/Remove K
IntelliScroll - Remove All C
Cine...
Label Palette ...
Show Text Overlay
Anonymize Text Overlay
Show Annotations
Angle
Freehand ROI
Elliptical ROI
Rectangular ROI
Bookmark Image B
Interactive ROI
Inverted ROI
S: 110
C: 512
W: 1024

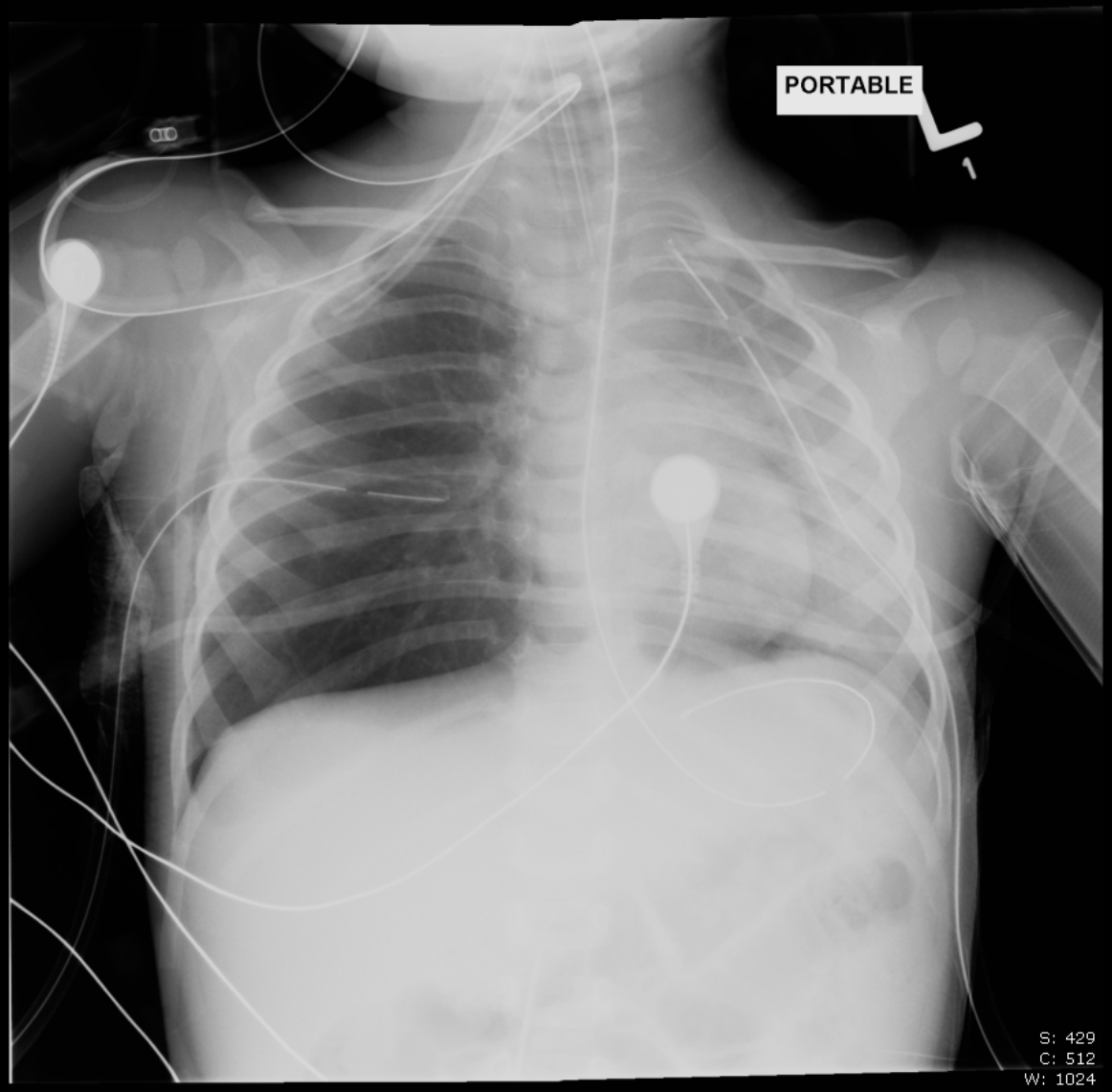
Chest image, uncompressed

Montana, Joe
9000009

11/5/1968
M

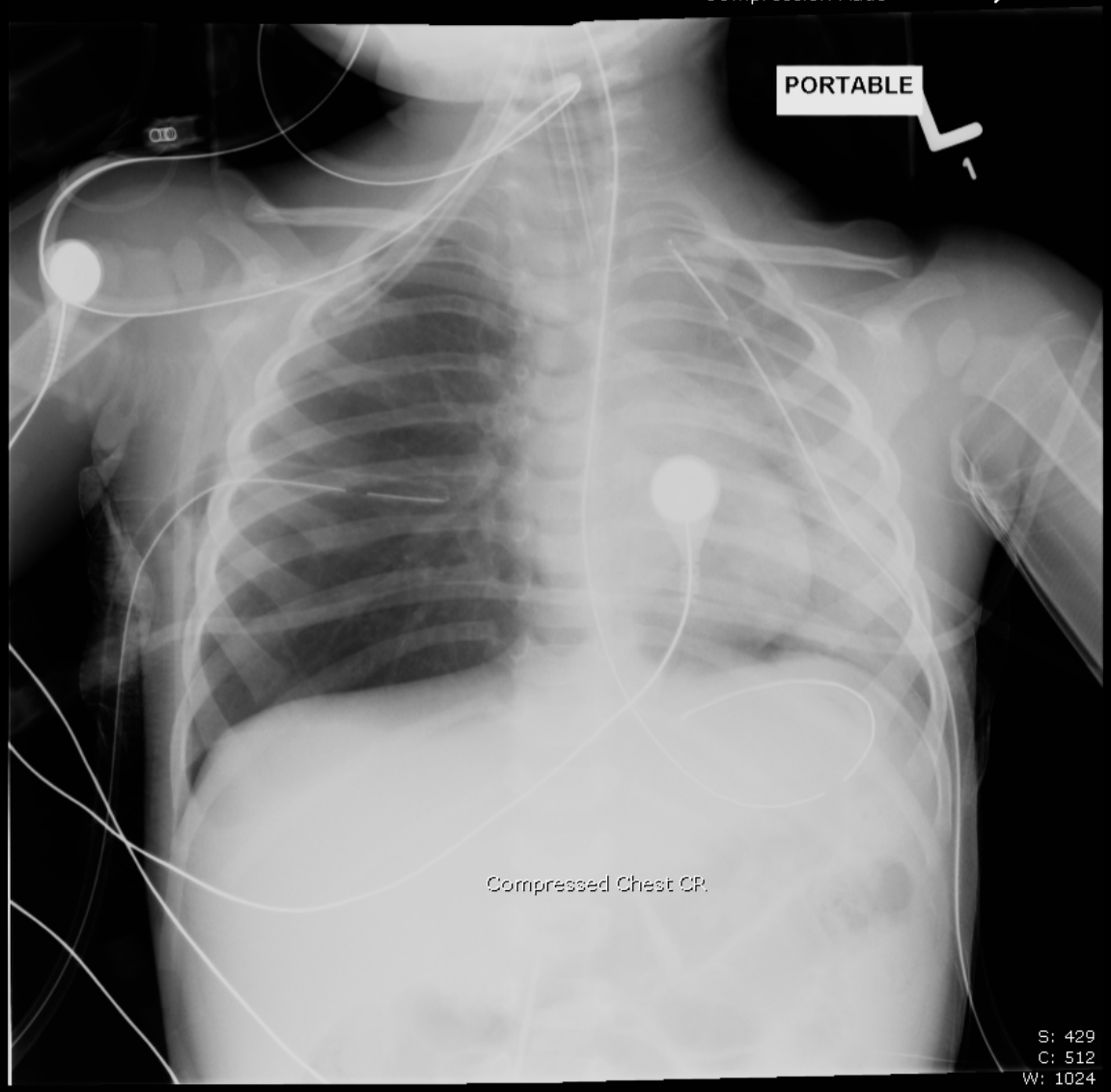
CHEST
10/14/2001 03:10:33
G000026

Uncompressed CR Chest

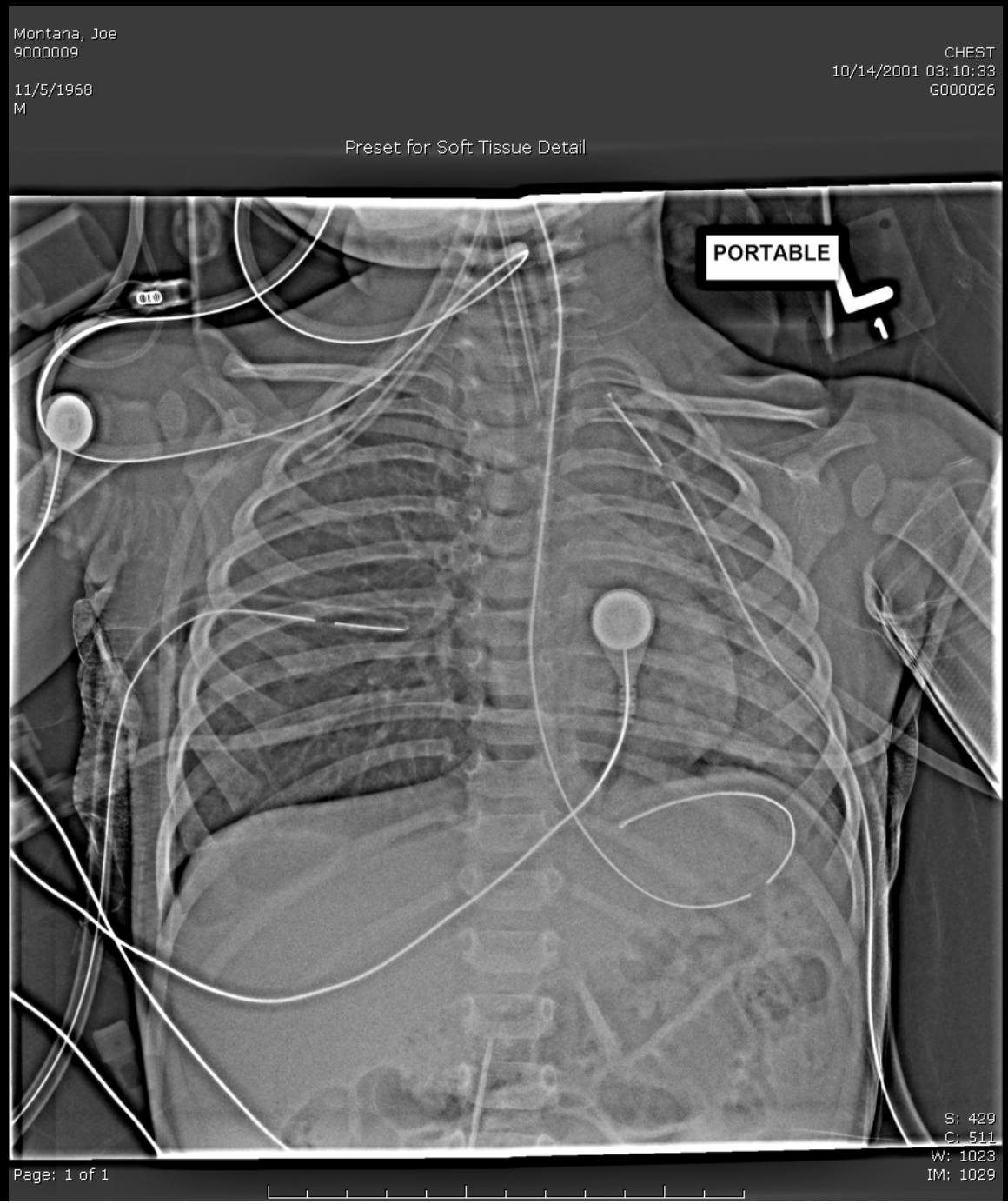



S: 429
C: 512
W: 1024
IM: 1029

Chest image, compressed 32:1


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
32:1
Compression Ratio
PORTABLE
Compressed Chest CR
S: 429
C: 512
W: 1024
IM: 1029
Page: 1 of 1

Chest image, soft tissue detail


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
Preset for Soft Tissue Detail
PORTABLE
S: 429
C: 511
W: 1023
IM: 1029
Page: 1 of 1

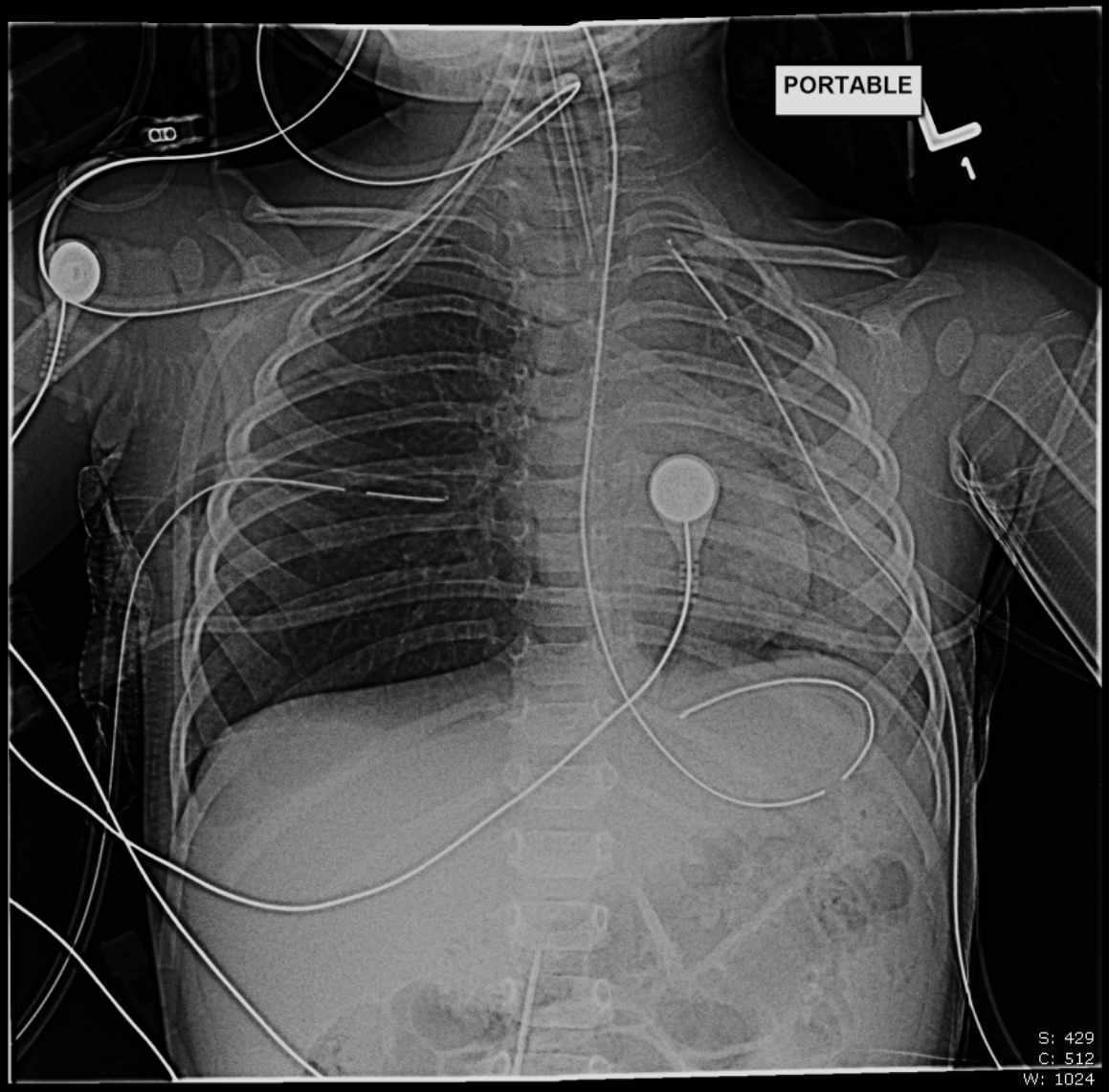
Chest image, line placement

Montana, Joe
9000009

11/5/1968
M

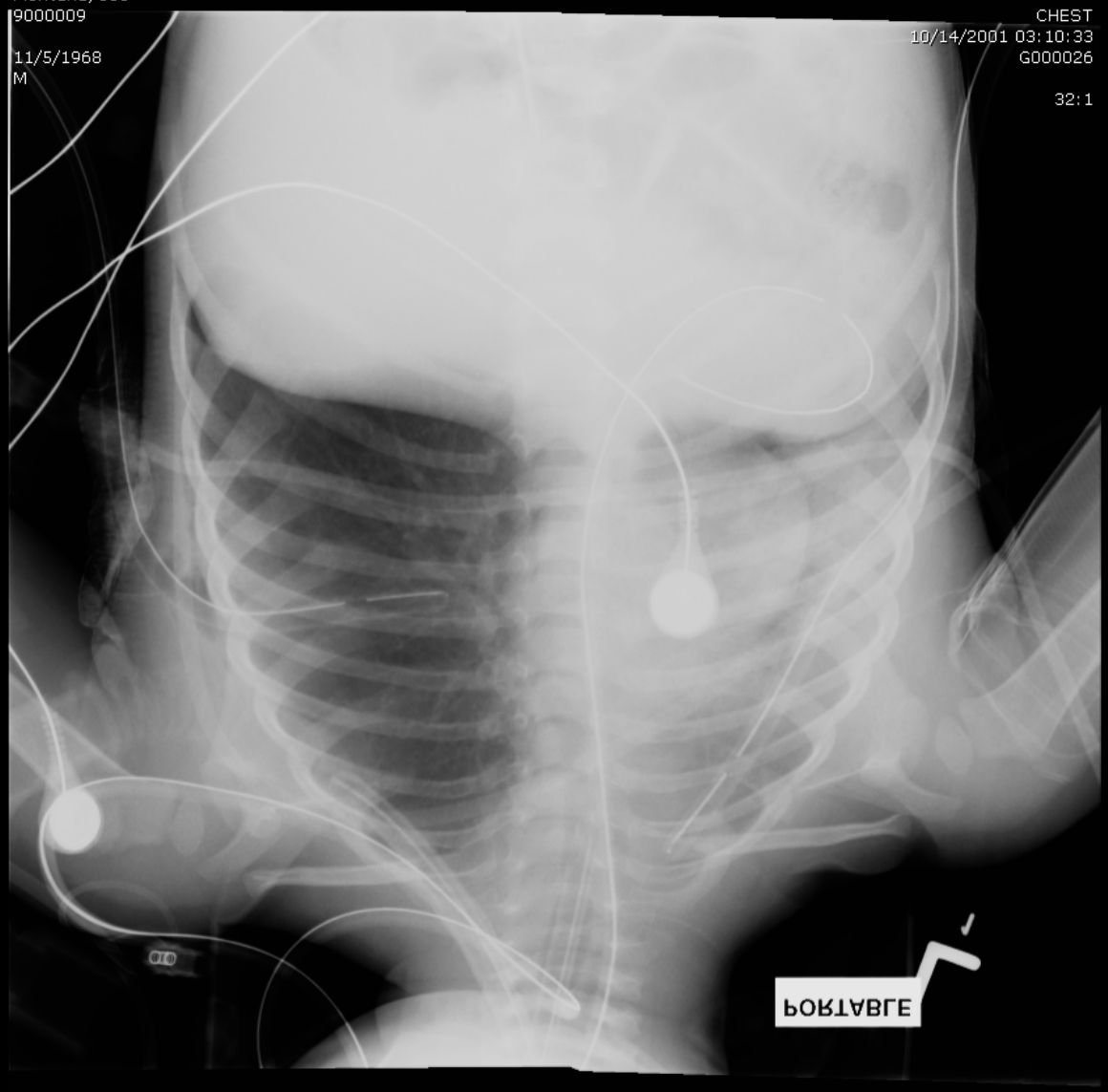
CHEST
10/14/2001 03:10:33
G000026

Preset for Chest Line Placement




S: 429
C: 512
W: 1024
IM: 1029

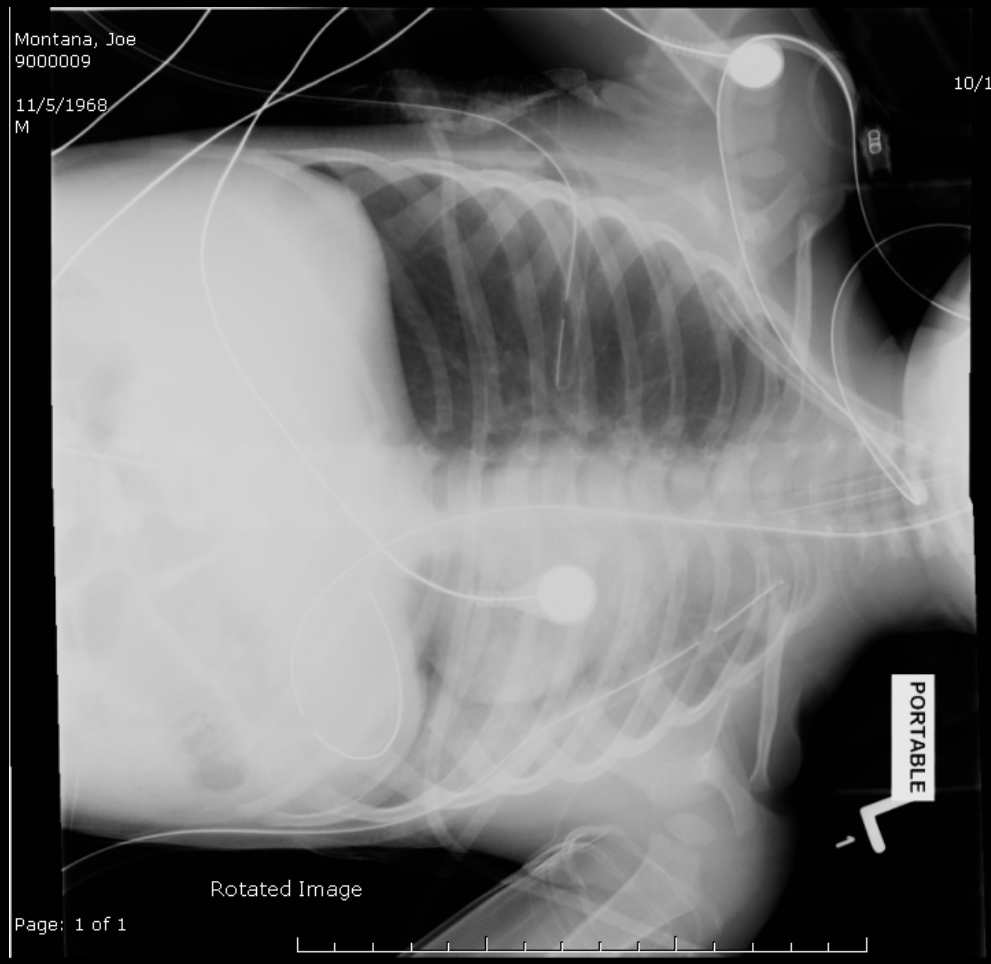
Chest image, examples of ‘flip’ function



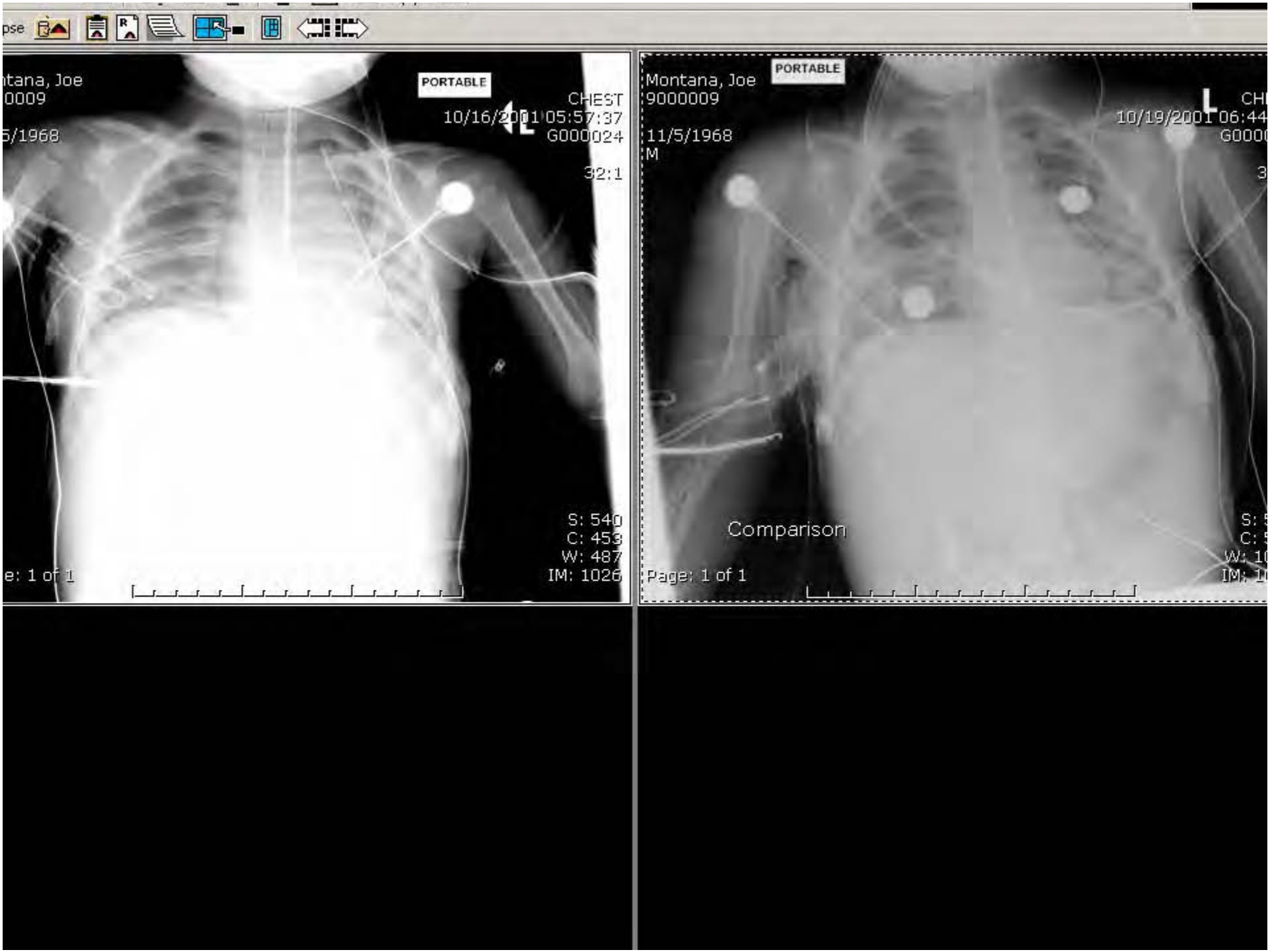

Flipped Image

S: 429
C: 512
W: 1024
IM: 1029

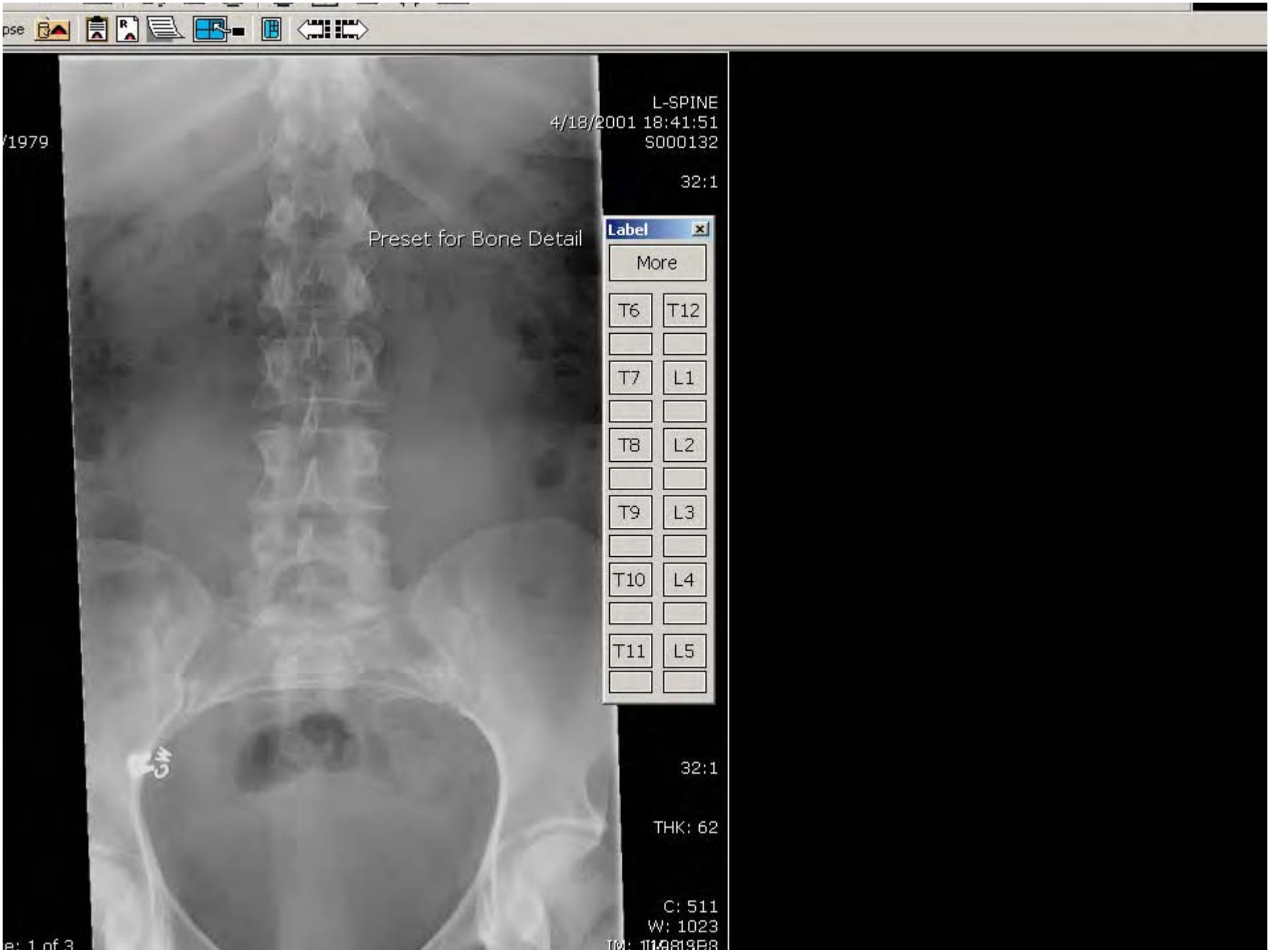
Page: 1 of 1


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
32:1
PORTABLE
Rotated Image
Page: 1 of 1
S: 429
C: 512
W: 1024
IM: 1029

Chest images, side by side comparison hanging protocol


PORTABLE
CHEST
10/16/2001 05:57:37
G0000024
32:1
S: 540
C: 453
W: 487
IM: 1026
Page: 1 of 1
Montana, Joe
9000009
11/5/1968
M
PORTABLE
10/19/2001 06:44
Comparison
Page: 1 of 1

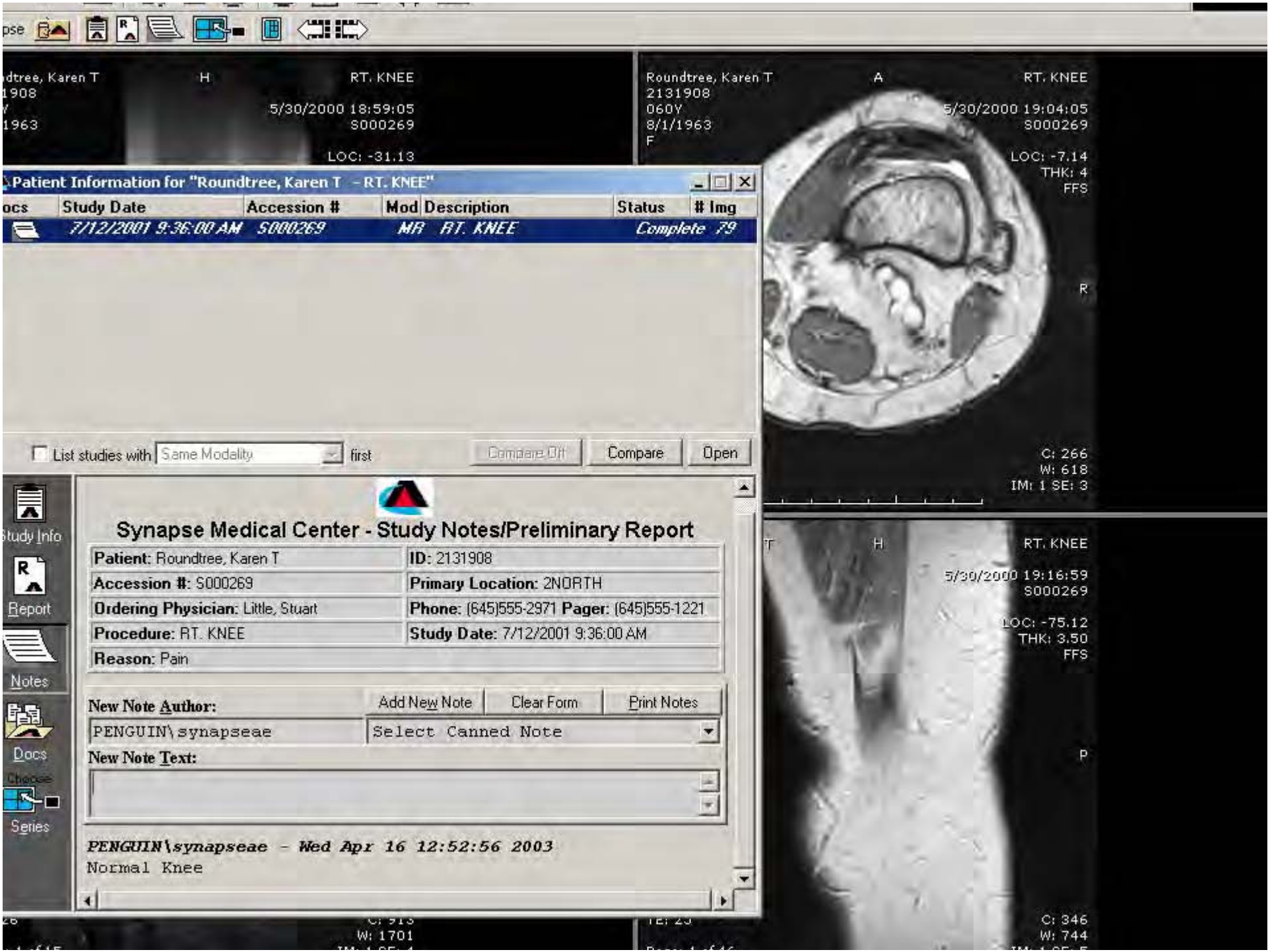
L-spine, bone detail


/1979
L-SPINE
4/18/2001 18:41:51
S000132
32:1
Preset for Bone Detail
Label
More
T6
T12
T7
L1
T8
L2
T9
L3
T10
L4
T11
L5
32:1
THK: 62
C: 511
W: 1023

Foot, showing magnification function and cm scale


FOOT
10/23/2001 19:56:22
G000028
S: 61
C: 512
W: 1024
IM: 1018

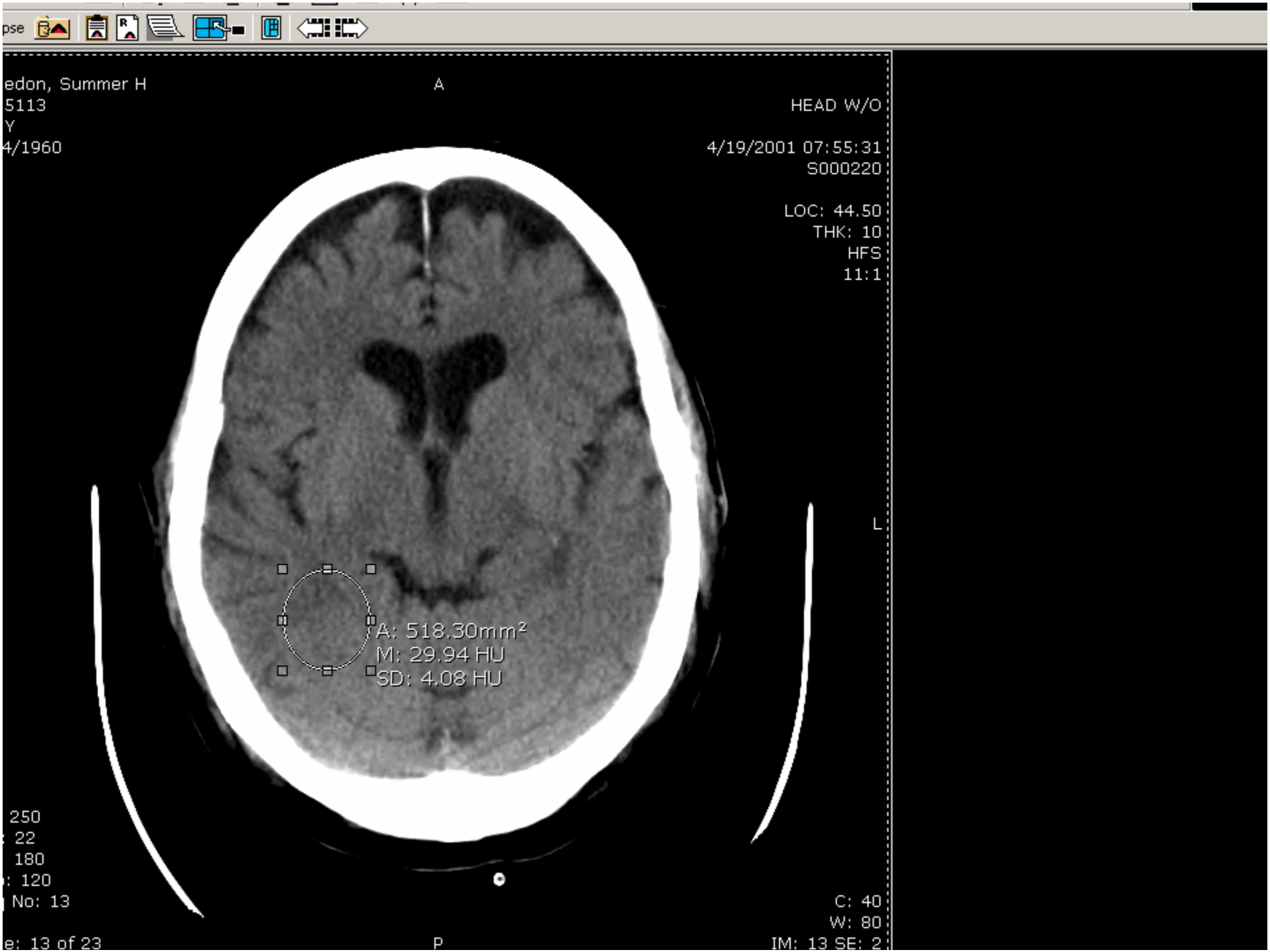
MRI image, showing patient information and ‘note’ function


dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 18:59:05
S000269
LOC: -31.13
Roundtree, Karen T
2131908
060Y
8/1/1963
F
A
RT. KNEE
5/30/2000 19:04:05
S000269
LOC: -7.14
THK: 4
FFS
R
C: 266
W: 618
IM: 1 SE: 3
Patient Information for "Roundtree, Karen T - RT. KNEE"
ocs
Study Date
Accession #
Mod
Description
Status
# Img
7/12/2001 9:36:00 AM
S000269
MR
RT. KNEE
Complete
79
List studies with
Same Modality
first
Compare Dif
Compare
Open
Study Info
Report
Notes
Docs
Choose
Series
Synapse Medical Center - Study Notes/Preliminary Report
Patient: Roundtree, Karen T
ID: 2131908
Accession #: S000269
Primary Location: 2NORTH
Ordering Physician: Little, Stuart
Phone: (645)555-2971 Pager: (645)555-1221
Procedure: RT. KNEE
Study Date: 7/12/2001 9:36:00 AM
Reason: Pain
New Note Author:
Add New Note
Clear Form
Print Notes
PENGUIN\synapseae
Select Canned Note
New Note Text:
PENGUIN\synapseae - Wed Apr 16 12:52:56 2003
Normal Knee
T
H
RT. KNEE
5/30/2000 19:16:59
S000269
LOC: -75.12
THK: 3.50
FFS
P
C: 346
W: 744
W: 1701

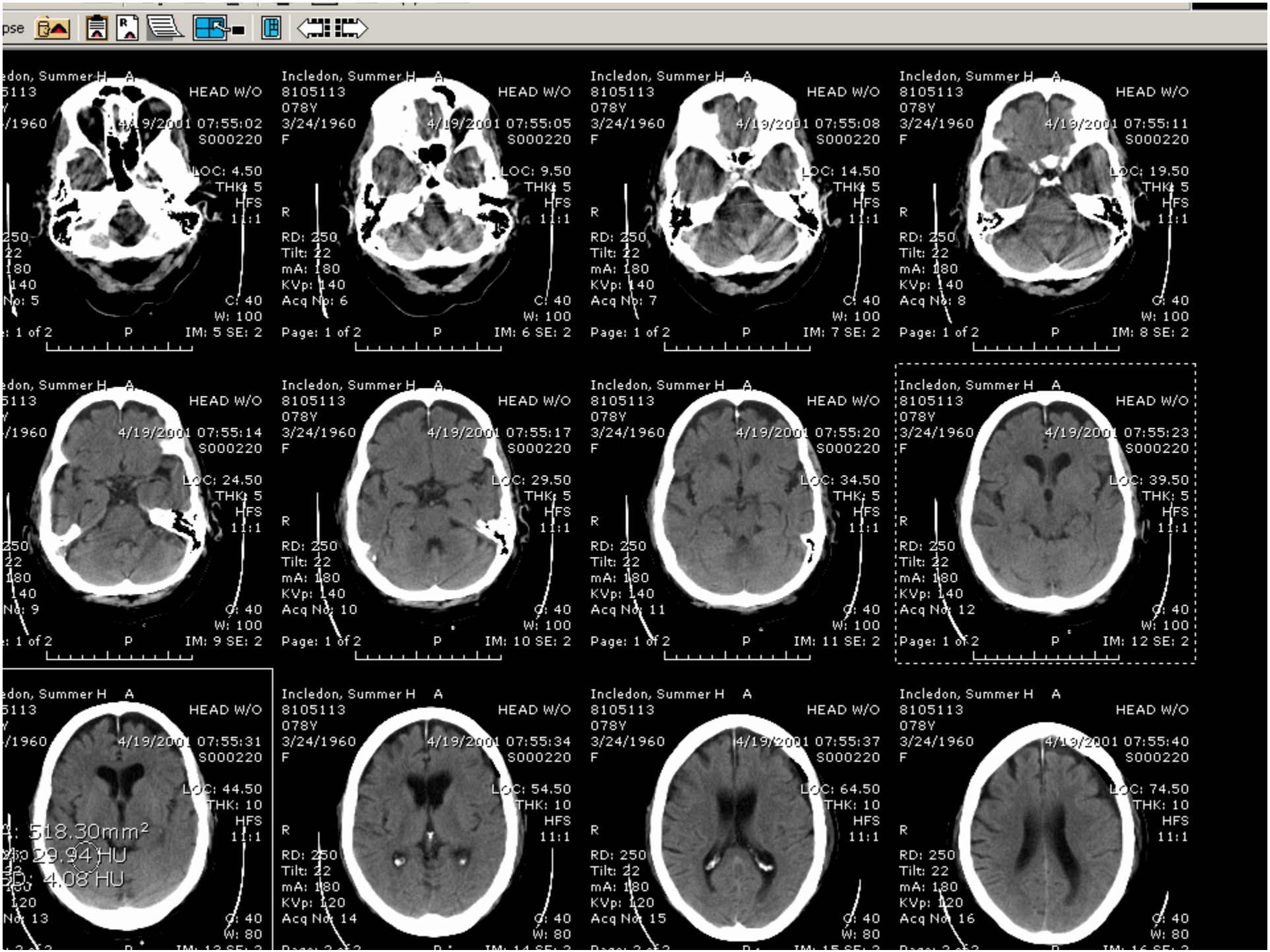
Knee MRI, showing multiple sequence hanging protocol and plane of interest function


dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 18:59:05
S000269
LOC: -31.13
THK: 10
FFS
P
E QUAD
20
10
4
C: 388
W: 806
IM: 1 SE: 2
: 1 of 3
Roundtree, Karen T
2131908
060Y
8/1/1963
F
A
RT. KNEE
5/30/2000 19:04:05
S000269
LOC: -7.14
THK: 4
FFS
L
R
KNEE QUAD
FE
FA: 35
TR: 660
TE: 15
C: 266
W: 618
Page: 1 of 15
45
25
1
M: 1 SE: 3
dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 19:08:21
S000269
LOC: -36.28
THK: 4
FFS
L
E QUAD
90
2000
26
1
25
45
C: 913
W: 1701
Roundtree, Karen T
2131908
060Y
8/1/1963
F
H
RT. KNEE
5/30/2000 19:16:59
S000269
LOC: -27.12
THK: 3.50
FFS
A
P
KNEE QUAD
SE
FA: 90
TR: 2500
TE: 25
C: 389
W: 750

Head CT, showing area of interest function


edon, Summer H
5113
Y
4/1960
A
HEAD W/O
4/19/2001 07:55:31
S000220
LOC: 44.50
THK: 10
HFS
11:1
L
A: 518.30mm²
M: 29.94 HU
SD: 4.08 HU
250
22
180
120
No: 13
C: 40
W: 80
e: 13 of 23
P
IM: 13 SE: 2

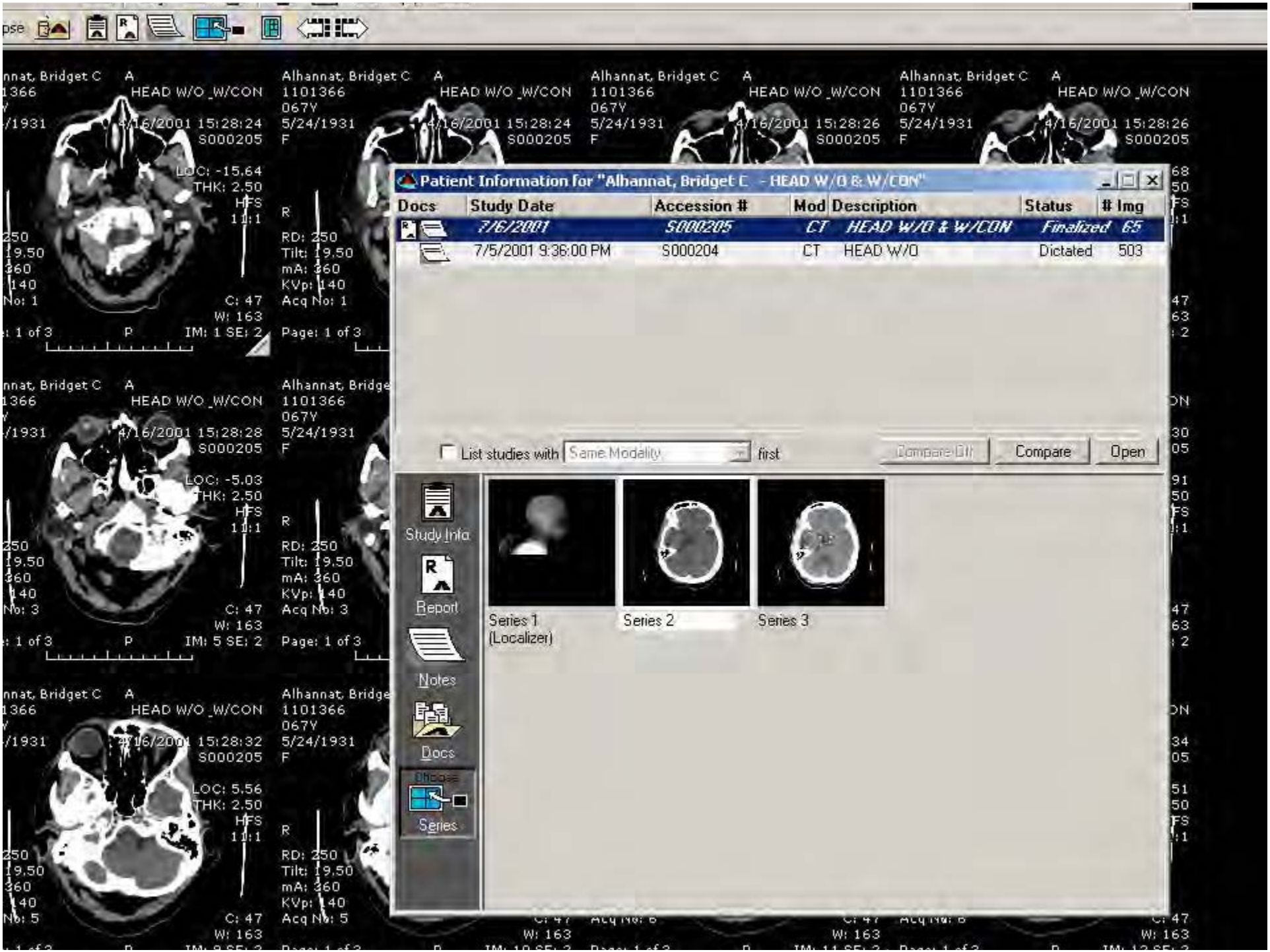
CT head, ‘tiling’ hanging protocol


Incledon, Summer H A
8105113
078Y
3/24/1960
F
HEAD W/O
4/19/2001 07:55:02
S000220
LOC: 4.50
THK: 5
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 140
Acq No: 5
C: 40
W: 100
Page: 1 of 2
P
IM: 5 SE: 2
4/19/2001 07:55:05
LOC: 9.50
Acq No: 6
IM: 6 SE: 2
4/19/2001 07:55:08
LOC: 14.50
Acq No: 7
IM: 7 SE: 2
4/19/2001 07:55:11
LOC: 19.50
Acq No: 8
IM: 8 SE: 2
4/19/2001 07:55:14
LOC: 24.50
Acq No: 9
IM: 9 SE: 2
4/19/2001 07:55:17
LOC: 29.50
Acq No: 10
IM: 10 SE: 2
4/19/2001 07:55:20
LOC: 34.50
Acq No: 11
IM: 11 SE: 2
4/19/2001 07:55:23
LOC: 39.50
Acq No: 12
IM: 12 SE: 2
4/19/2001 07:55:31
LOC: 44.50
THK: 10
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 120
Acq No: 13
C: 40
W: 80
518.30mm²
29.94 HU
4.08 HU
4/19/2001 07:55:34
LOC: 54.50
Acq No: 14
4/19/2001 07:55:37
LOC: 64.50
Acq No: 15
4/19/2001 07:55:40
LOC: 74.50
Acq No: 16

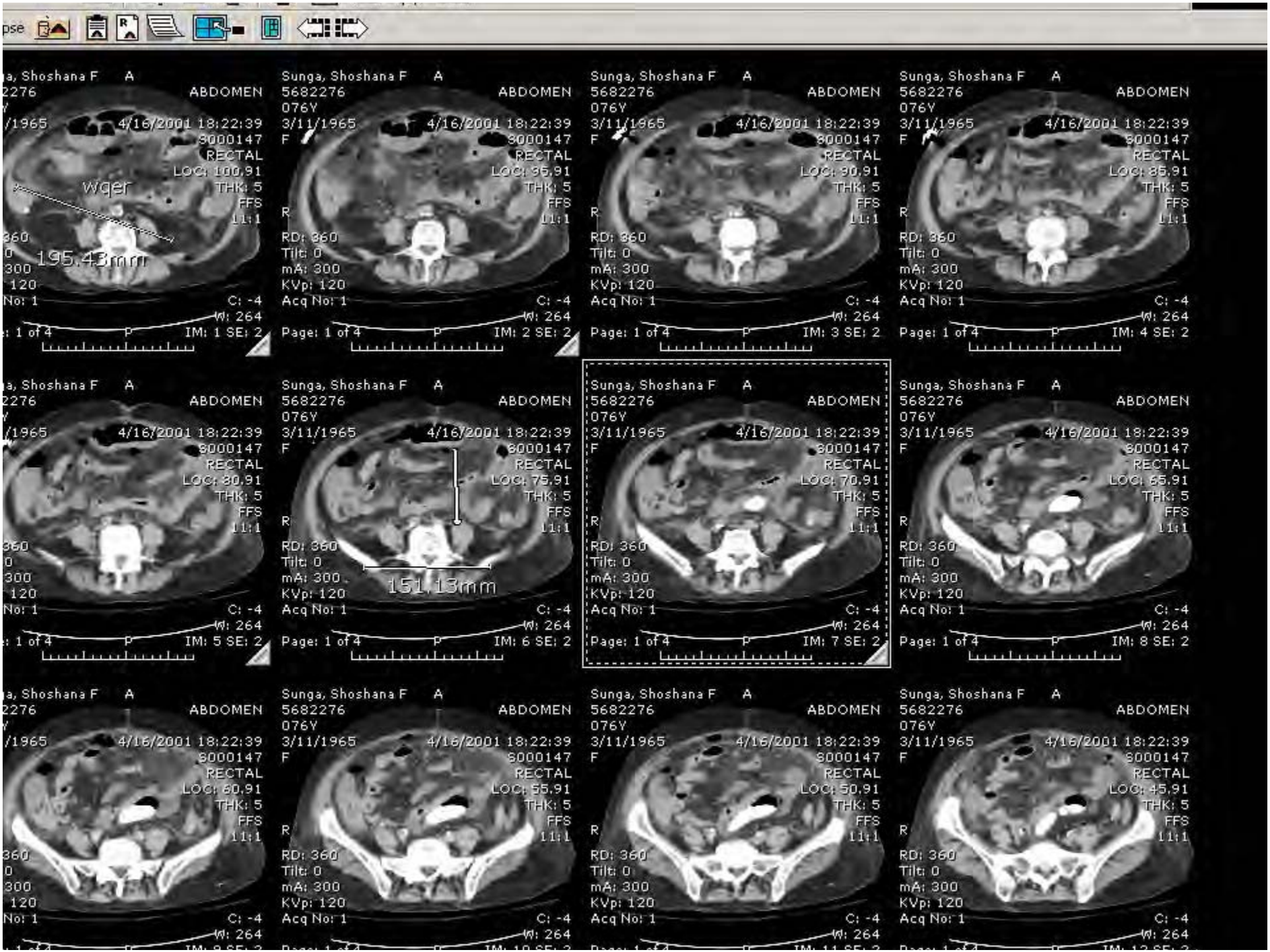
Head CT, showing pull down menu for choosing presets


Incledon, Summer H A
8105113
078Y
3/24/1960
F
HEAD W/O
4/19/2001 07:55:02
S000220
LOC: 4.50
THK: 5
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 140
Acq No: 5
C: 50
W: 150
Page: 1 of 2
P
IM: 5 SE: 2
4/19/2001 07:55:05
LOC: 9.50
Acq No: 6
IM: 6 SE: 2
4/19/2001 07:55:08
LOC: 14.50
Acq No: 7
IM: 8 SE: 2
4/19/2001 07:55:11
LOC: 19.50
4/19/2001 07:55:14
LOC: 24.50
Acq No: 9
IM: 9 SE: 2
4/19/2001 07:55:17
LOC: 29.50
Acq No: 10
IM: 10 SE: 2
4/19/2001 07:55:23
LOC: 39.50
Acq No: 11
4/19/2001 07:55:31
LOC: 44.50
THK: 10
Acq No: 13
4/19/2001 07:55:34
LOC: 54.50
Acq No: 14
4/19/2001 07:55:40
LOC: 74.50
Acq No: 16
Window Level
Zoom
Pan
Ruler R
Text T
Arrow A
Density Value D
Lock Tools L
Image Presets
Scale, Rotate, Flip
Tools
Reference Lines
Apply Tools
Save Image
AON Factor
Copy To Clipboard
Tile Formats
IntelliLink I
IntelliScroll S
IntelliScroll Add/Remove K
IntelliScroll - Remove All C
Cine...
Print...
Bone NUMPAD 0
Abdomen NUMPAD 1
Lung NUMPAD 2
BRAIN NUMPAD 3
Liver NUMPAD 5
Spines NUMPAD 4
Scout NUMPAD 6
Revert NUMPAD 9
Invert

CT head, showing menu for choosing image series


Alhannat, Bridget C A
1101366
HEAD W/O _W/CON
067Y
5/24/1931
F
4/16/2001 15:28:24
S000205
LOC: -15.64
THK: 2.50
HFS
11:1
RD: 250
Tilt: 19.50
mA: 360
KVp: 140
Acq No: 1
C: 47
W: 163
Page: 1 of 3
Patient Information for "Alhannat, Bridget C - HEAD W/O & W/CON"
Docs
Study Date
Accession #
Mod
Description
Status
# Img
7/6/2001
S000205
CT
HEAD W/O & W/CON
Finalized
65
7/5/2001 9:36:00 PM
S000204
CT
HEAD W/O
Dictated
503
List studies with
Same Modality
first
Compare Dif
Compare
Open
Study Info
Report
Notes
Docs
Series
Series 1
(Localizer)
Series 2
Series 3

CT abdomen, ‘tiling’ hanging protocol


Sunga, Shoshana F A
5682276
076Y
3/11/1965 F
ABDOMEN
4/16/2001 18:22:39
S000147
RECTAL
LOC: 100.91
LOC: 95.91
LOC: 90.91
LOC: 85.91
LOC: 80.91
LOC: 75.91
LOC: 70.91
LOC: 65.91
LOC: 60.91
LOC: 55.91
LOC: 50.91
LOC: 45.91
THK: 5
FFS
11:1
R
RD: 360
Tilt: 0
mA: 300
KVp: 120
Acq No: 1
C: -4
W: 264
wqer
195.43mm
151.13mm
Page: 1 of 4
IM: 1 SE: 2
IM: 2 SE: 2
IM: 3 SE: 2
IM: 4 SE: 2
IM: 5 SE: 2
IM: 6 SE: 2
IM: 7 SE: 2
IM: 8 SE: 2

PACS training is necessary for optimum patient care

Ref 3

# Goals of PACS education c. 1990

- Learn to retrieve images and reports and display them on a workstation
- Learn to use the workstation tools to enhance the images

Refs 3, 13

# Goals of PACS education c. 1995

- All of the above, plus…

- Customize the workstation to the user's preference
  - Hanging protocols
  - Image orientation
- Interface the PACS with the radiology information system (RIS)
  - Worklists
  - Exam schedules

Ref 13

PACS training should be tailored to the requirements of the different physician and surgical specialties

Ref 3

PACS training should be carried out individually or in small groups (same specialty)

Ref 3

Clinician training - 1 hour (30 -45 minutes of demonstration, 15 - 30 minutes of hands on experience

Ref 3

# Paradigm shift in viewing techniques

- Multiple viewboxes vs one or two monitors
- Use bright light vs change contrast function on workstation
- Hold film vs hold mouse

# Paradigm shift …

- Use hand held magnifying glass vs use magnify function on workstation
- Measure distances and angles with ruler and goniometer vs measure distances and angles with measuring functions on workstation

# Paradigm shift …

- Draw on image with wax pencil vs annotate image using keyboard and / or draw function on workstation
- Remove film from jacket for future use vs access images from office or home PC via secure internet connection and / or burn a CD

# Paradigm shift …

- Search through folder for the previous films vs previous studies automatically displayed along with the current study

# Viewing habits

- Early on, people use ‘tile mode’ for viewing CT’s. This reflects their experience with hard copy film.
- After using PACS for a while, most people view CT’s in ‘stack mode’
- Interpretation of CT’s is more rapid when viewed in ‘stack mode’

Ref 25

# Conclusion

PACS requires a change in the way we view images, but provides improved workflow, improved throughput, improved accessibility to images, ability to manipulate images, and improved communication capability, all geared to the goal of improving patient care.

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# PACS Workstations

# Workstations

- High resolution monitors (‘standard’ is 2 megapixels, but can be up to 4 megapixels)
- Increased resolution --> increased cost
- 1, 2, 4 or 8 monitors?

# Viewing Workstation

- Receives the images
- Presents the images for viewing
- Has image processor functions available

Ref 13

# Workstation functions

- Change contrast
- Invert gray scale
- Flip
- Rotate
- Magnify

# Workstation functions cont'd …

- Pan
- Zoom
- Measure
  - Linear distance, area, angle, density

# Workstation functions cont'd …

- Set individual preferences
  - Hanging protocols
  - Image orientation
- Worklists
- Automatic retrieval of comparison images

PACS screen images
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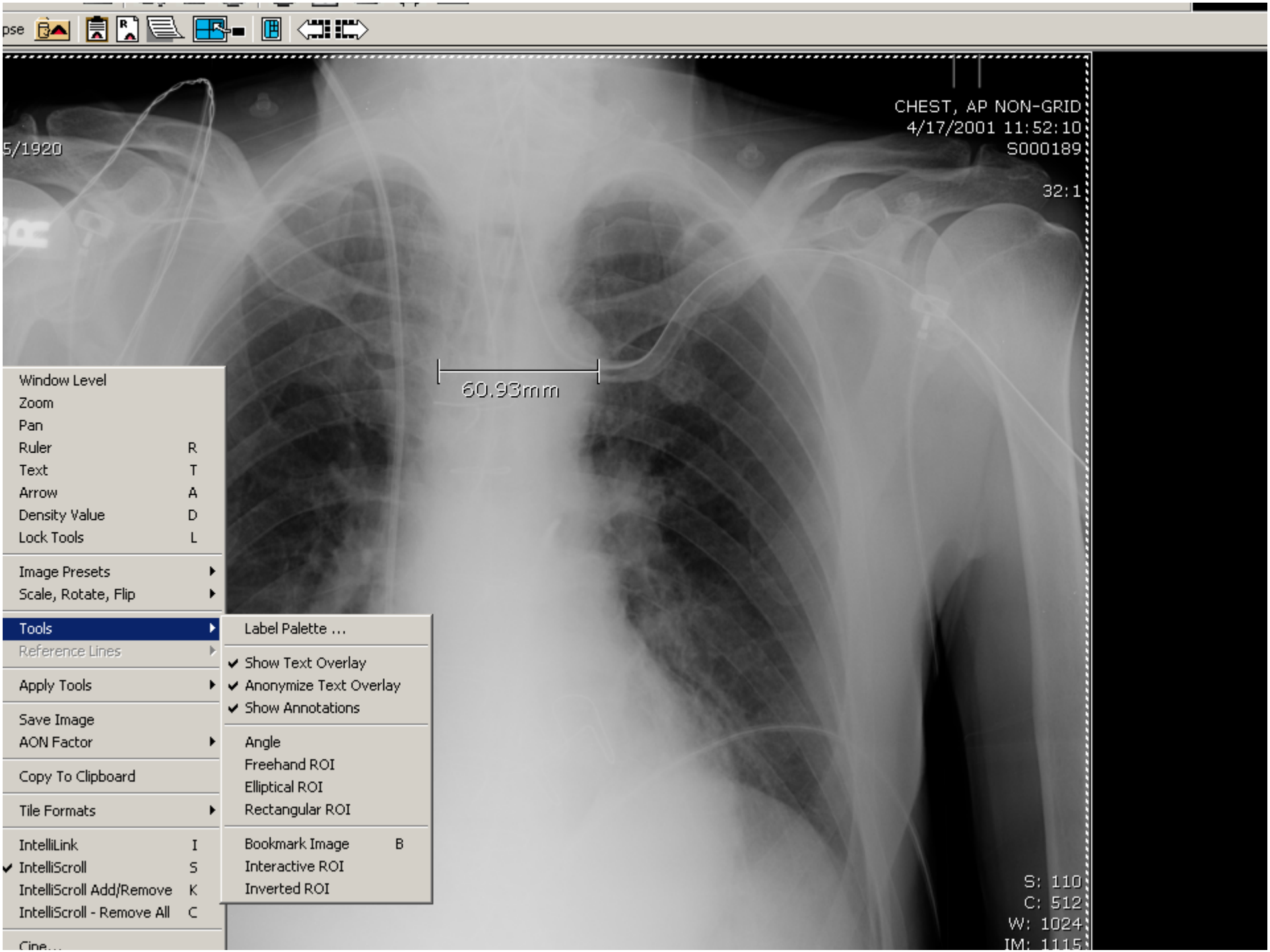
Chest image with tool bar and pull down menus


5/1920
CHEST, AP NON-GRID
4/17/2001 11:52:10
S000189
32:1
60.93mm
Window Level
Zoom
Pan
Ruler R
Text T
Arrow A
Density Value D
Lock Tools L
Image Presets
Scale, Rotate, Flip
Tools
Reference Lines
Apply Tools
Save Image
AON Factor
Copy To Clipboard
Tile Formats
IntelliLink I
IntelliScroll S
IntelliScroll Add/Remove K
IntelliScroll - Remove All C
Cine...
Label Palette ...
Show Text Overlay
Anonymize Text Overlay
Show Annotations
Angle
Freehand ROI
Elliptical ROI
Rectangular ROI
Bookmark Image B
Interactive ROI
Inverted ROI
S: 110
C: 512
W: 1024

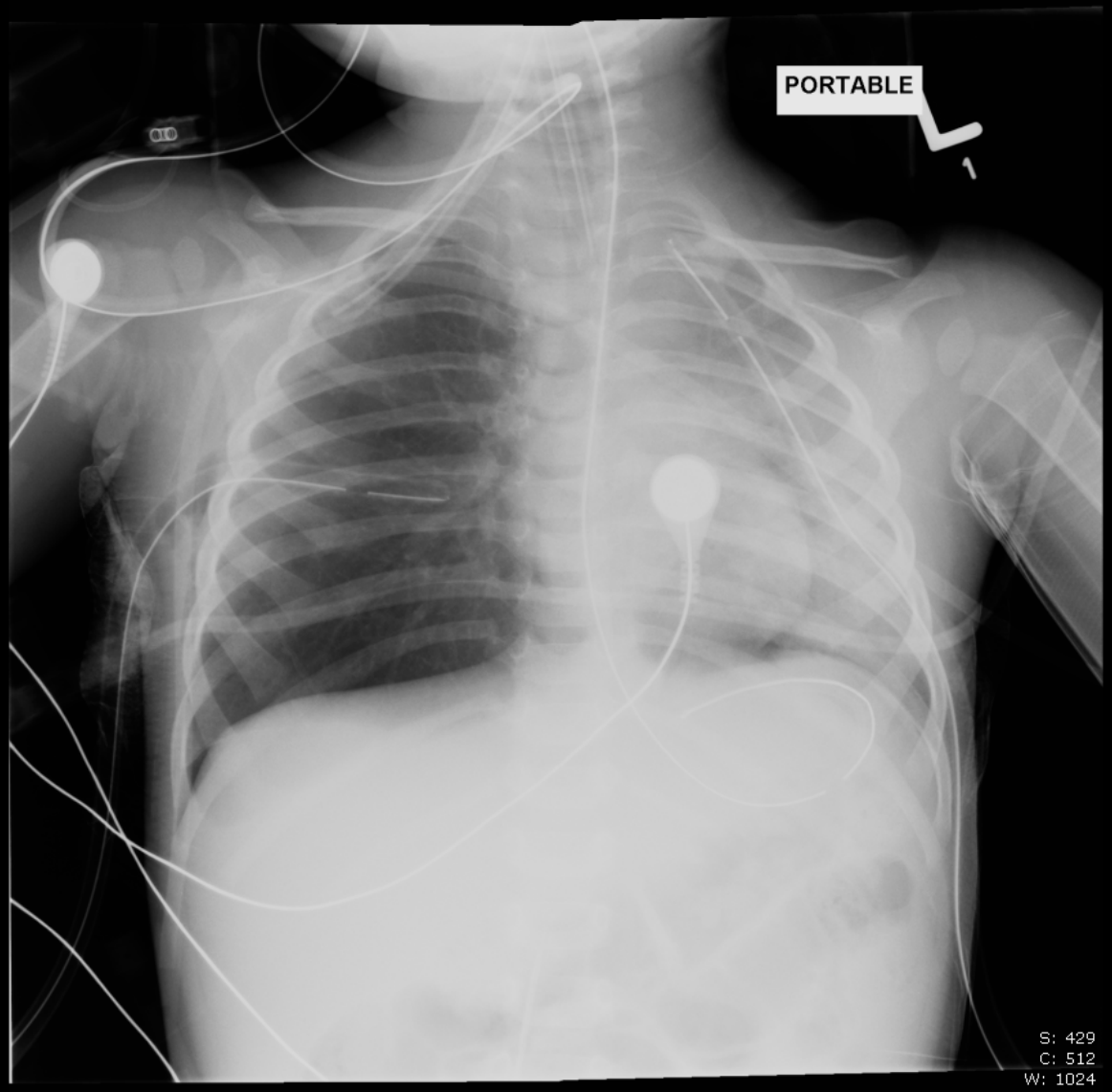
Chest image, uncompressed

Montana, Joe
9000009

11/5/1968
M

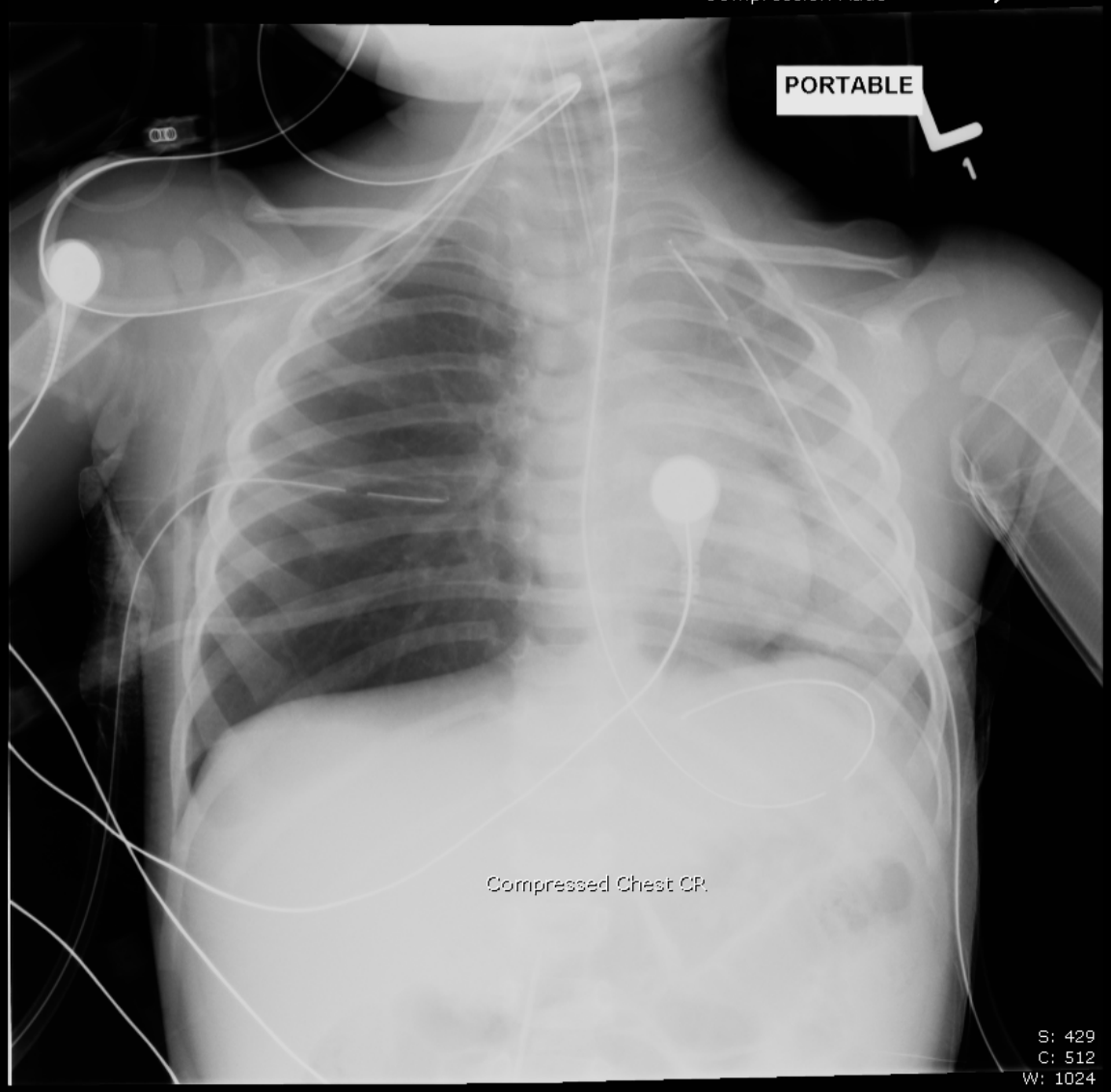
CHEST
10/14/2001 03:10:33
G000026

Uncompressed CR Chest

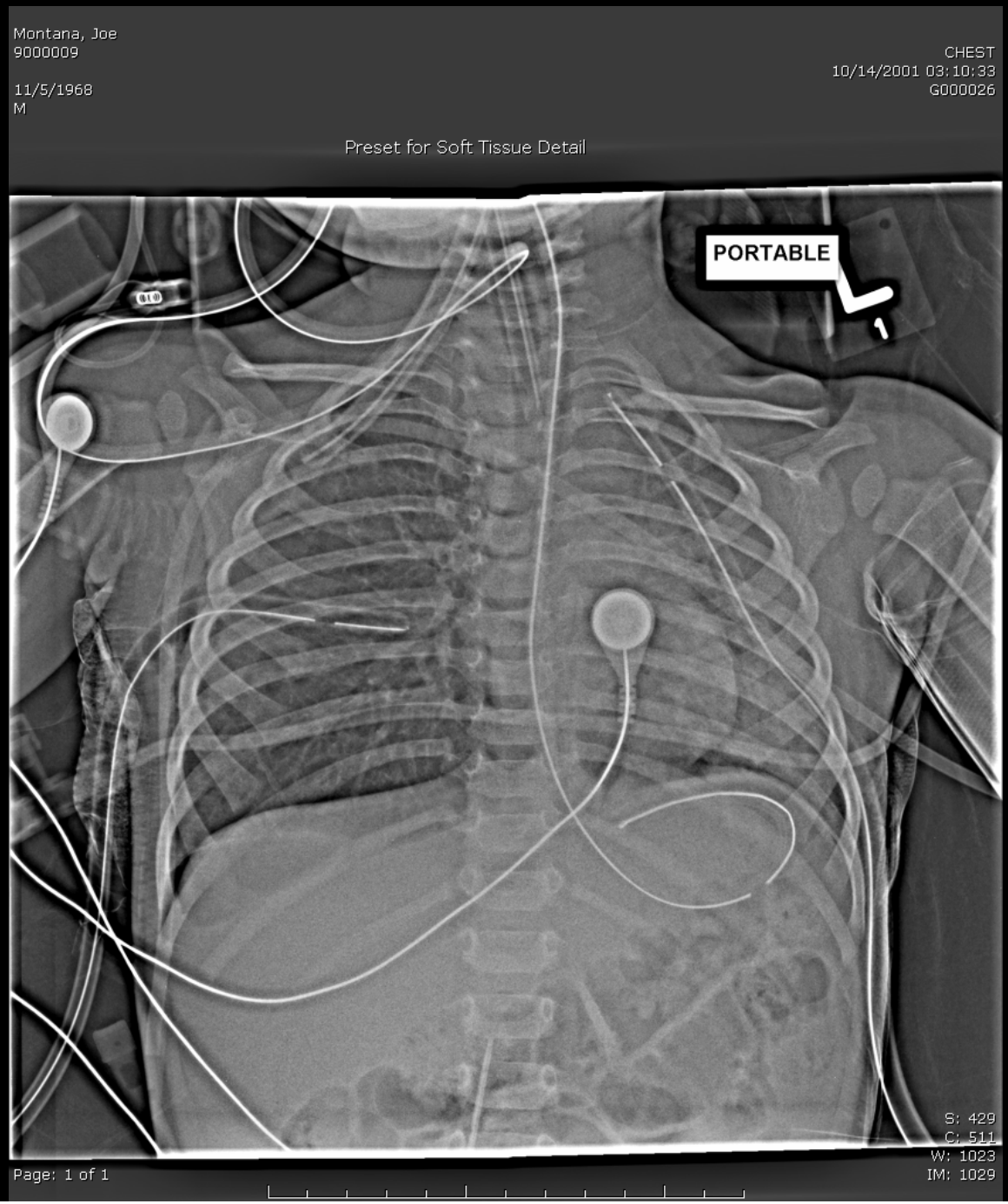



S: 429
C: 512
W: 1024
IM: 1029

Chest image, compressed 32:1


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
32:1
Compression Ratio
PORTABLE
Compressed Chest CR
S: 429
C: 512
W: 1024
IM: 1029
Page: 1 of 1

Chest image, soft tissue detail


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
Preset for Soft Tissue Detail
PORTABLE
S: 429
C: 511
W: 1023
IM: 1029
Page: 1 of 1

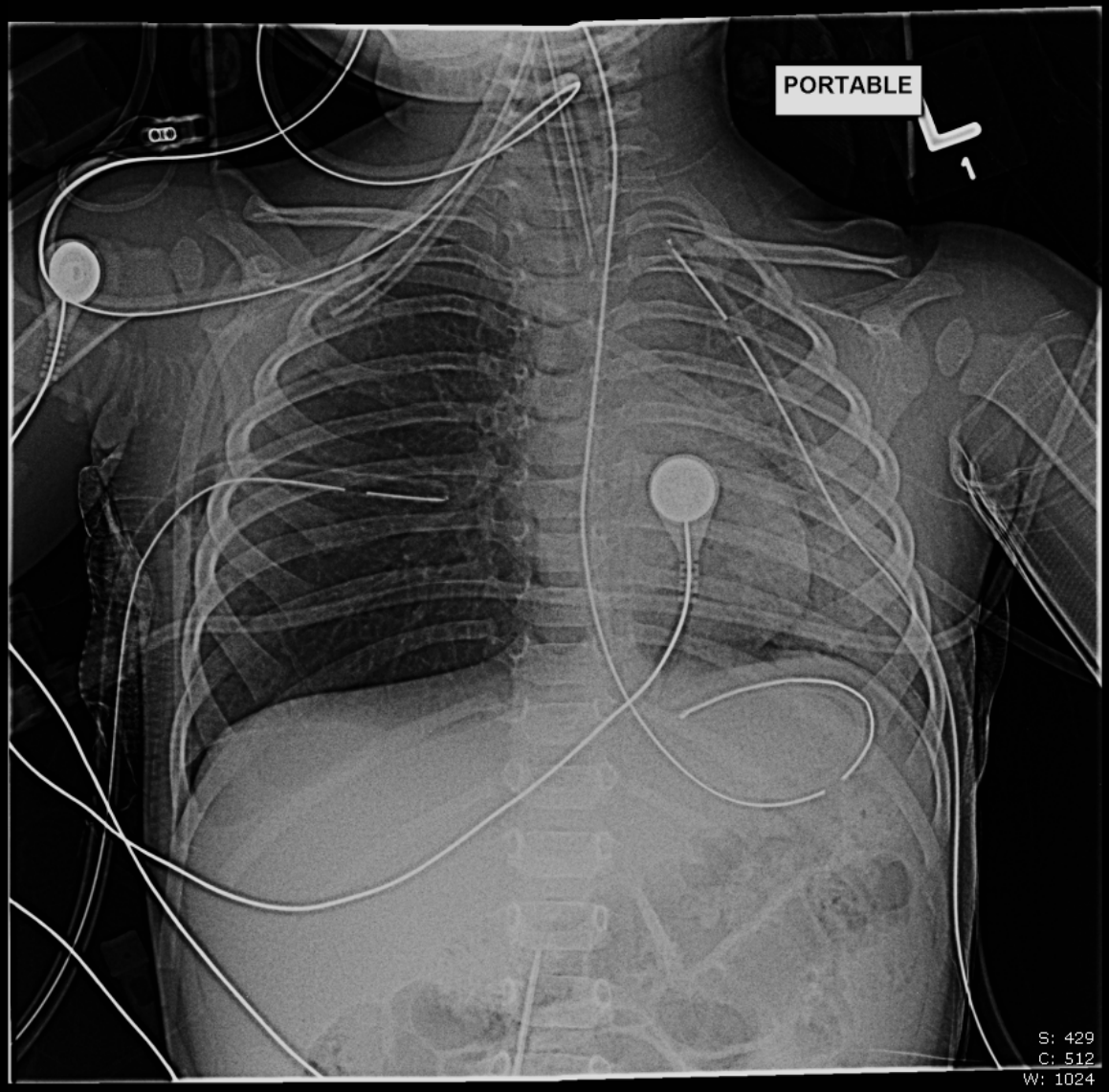
Chest image, line placement

Montana, Joe
9000009

11/5/1968
M

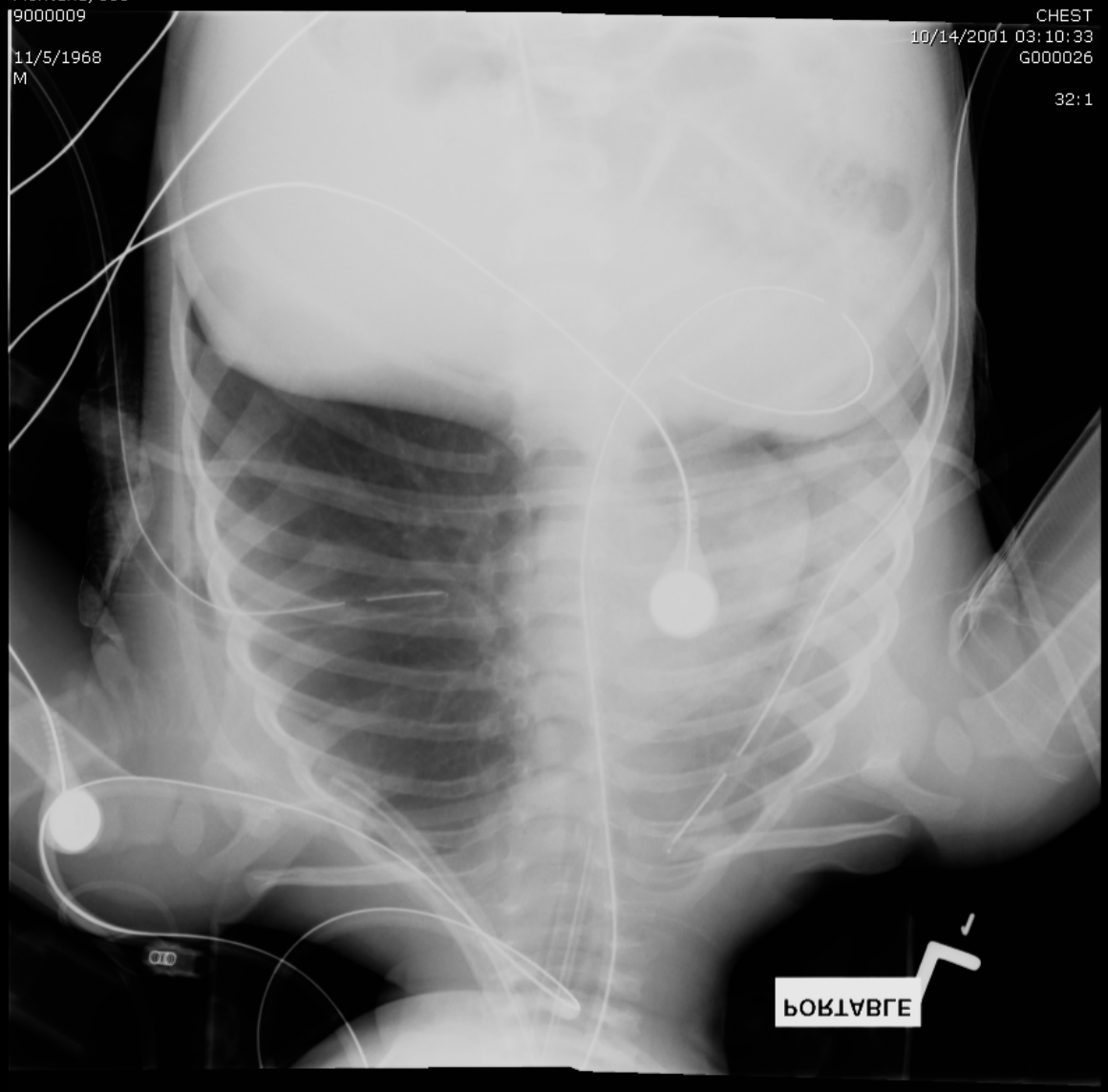
CHEST
10/14/2001 03:10:33
G000026

Preset for Chest Line Placement




S: 429
C: 512
W: 1024
IM: 1029

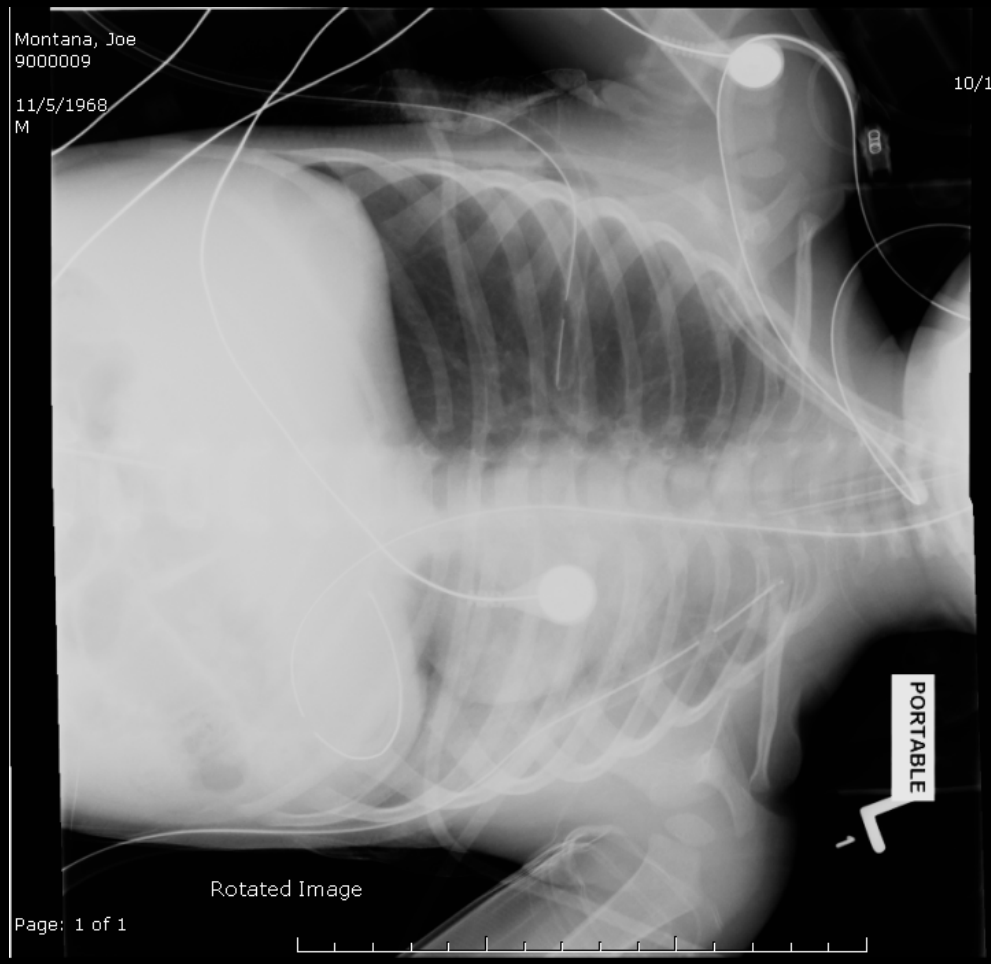
Chest image, examples of ‘flip’ function



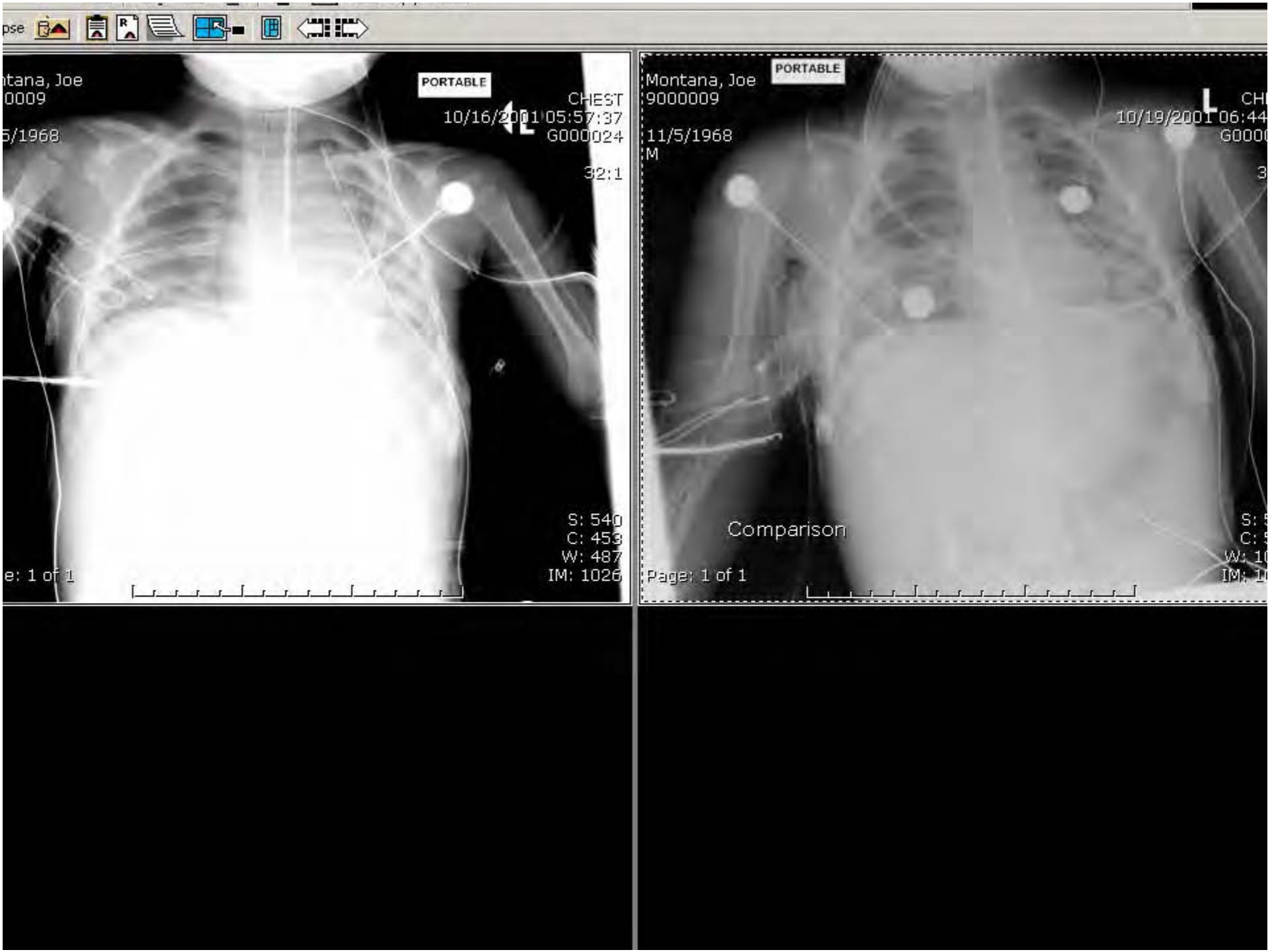

Flipped Image

S: 429
C: 512
W: 1024
IM: 1029

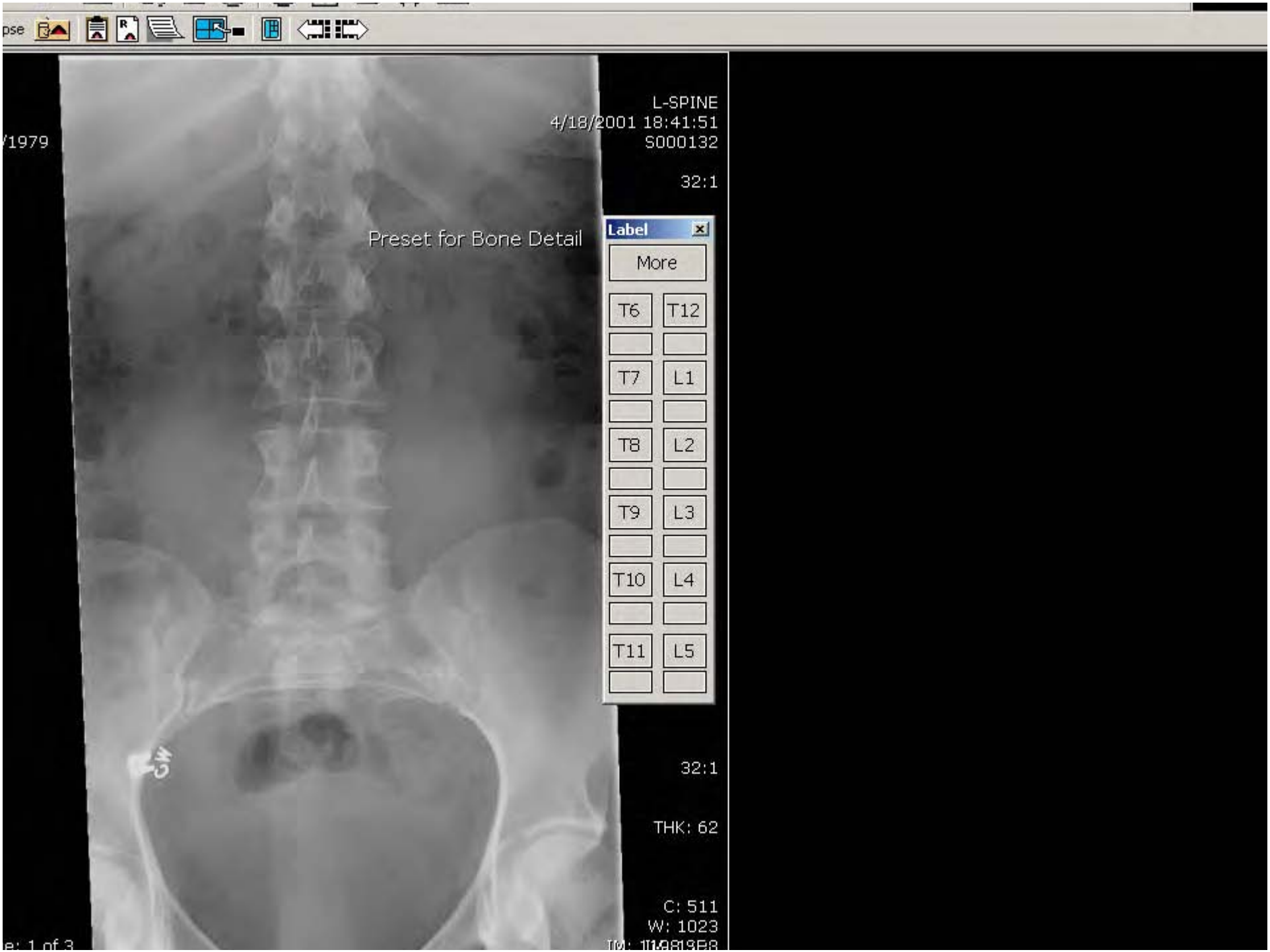
Page: 1 of 1


Montana, Joe
9000009
11/5/1968
M
CHEST
10/14/2001 03:10:33
G000026
32:1
PORTABLE
Rotated Image
Page: 1 of 1
S: 429
C: 512
W: 1024
IM: 1029

Chest images, side by side comparison hanging protocol


PORTABLE
CHEST
10/16/2001 05:57:37
G0000024
32:1
S: 540
C: 453
W: 487
IM: 1026
Page: 1 of 1
Montana, Joe
9000009
11/5/1968
M
PORTABLE
10/19/2001 06:44
Comparison
Page: 1 of 1

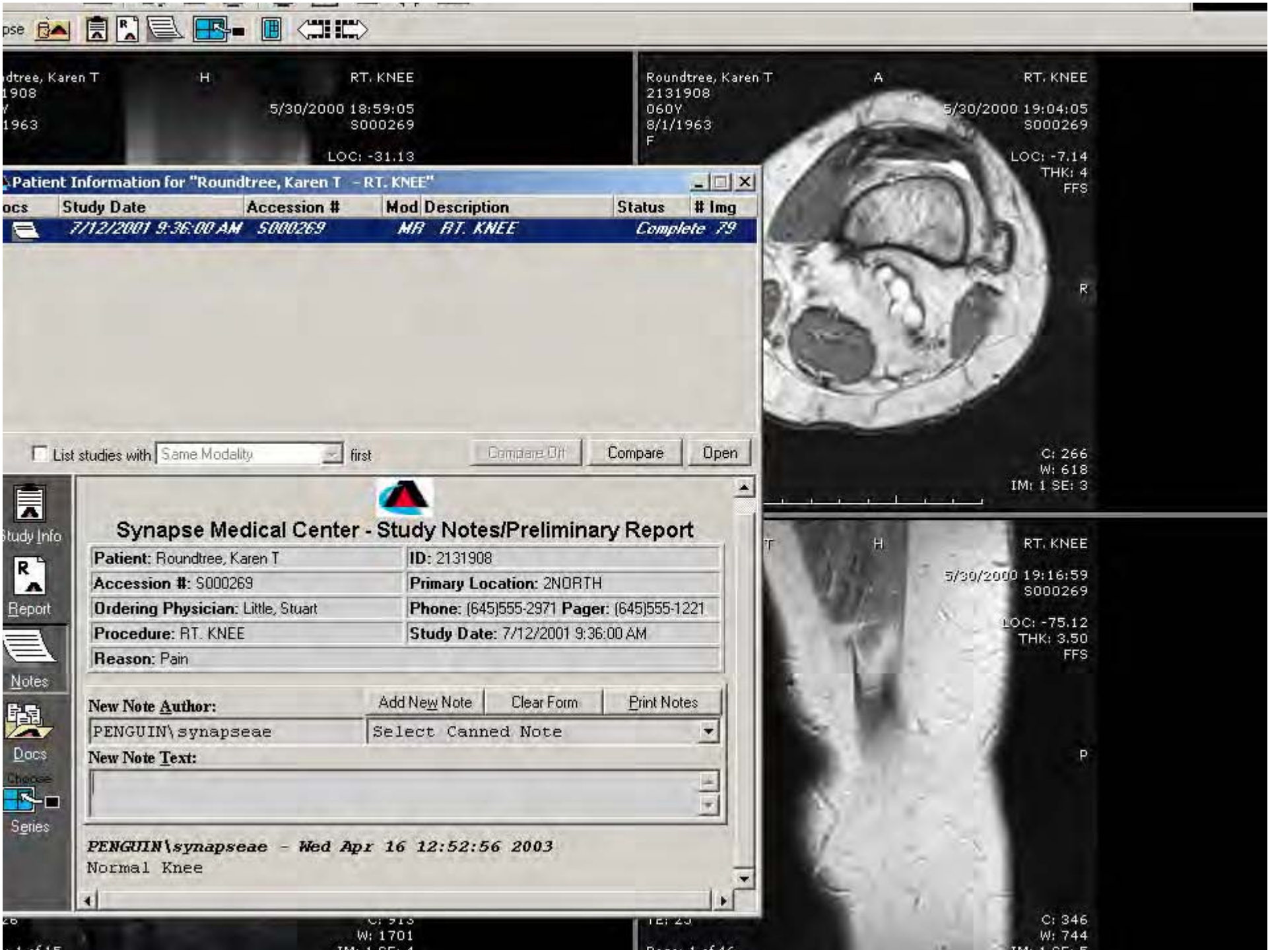
L-spine, bone detail


/1979
L-SPINE
4/18/2001 18:41:51
S000132
32:1
Preset for Bone Detail
Label
More
T6
T12
T7
L1
T8
L2
T9
L3
T10
L4
T11
L5
32:1
THK: 62
C: 511
W: 1023

Foot, showing magnification function and cm scale


FOOT
10/23/2001 19:56:22
G000028
S: 61
C: 512
W: 1024
IM: 1018

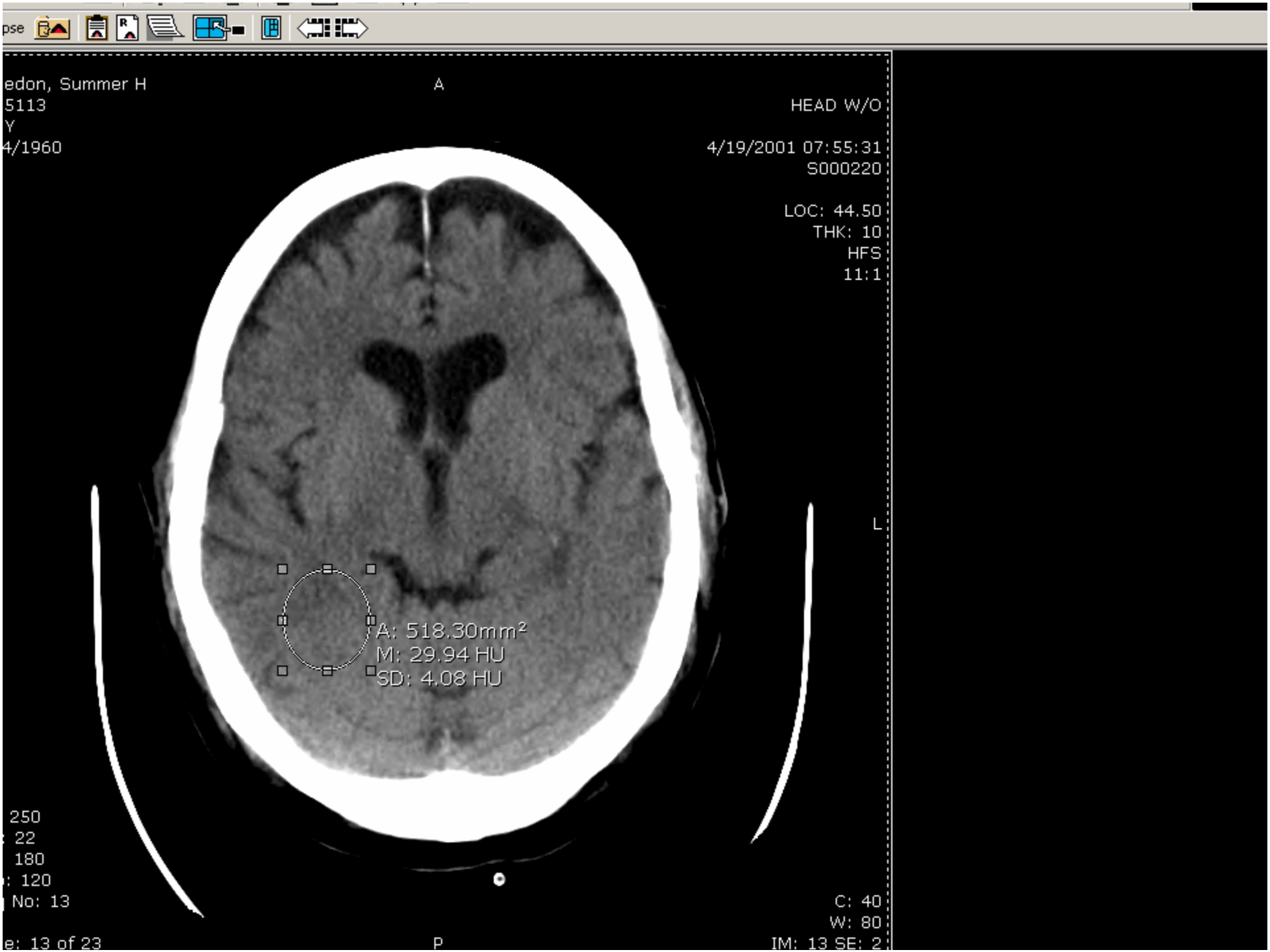
MRI image, showing patient information and ‘note’ function


dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 18:59:05
S000269
LOC: -31.13
Roundtree, Karen T
2131908
060Y
8/1/1963
F
A
RT. KNEE
5/30/2000 19:04:05
S000269
LOC: -7.14
THK: 4
FFS
R
C: 266
W: 618
IM: 1 SE: 3
Patient Information for "Roundtree, Karen T - RT. KNEE"
ocs
Study Date
Accession #
Mod
Description
Status
# Img
7/12/2001 9:36:00 AM
S000269
MR
RT. KNEE
Complete
79
List studies with
Same Modality
first
Compare Dif
Compare
Open
Study Info
Report
Notes
Docs
Choose
Series
Synapse Medical Center - Study Notes/Preliminary Report
Patient: Roundtree, Karen T
ID: 2131908
Accession #: S000269
Primary Location: 2NORTH
Ordering Physician: Little, Stuart
Phone: (645)555-2971 Pager: (645)555-1221
Procedure: RT. KNEE
Study Date: 7/12/2001 9:36:00 AM
Reason: Pain
New Note Author:
Add New Note
Clear Form
Print Notes
PENGUIN\synapseae
Select Canned Note
New Note Text:
PENGUIN\synapseae - Wed Apr 16 12:52:56 2003
Normal Knee
T
H
RT. KNEE
5/30/2000 19:16:59
S000269
LOC: -75.12
THK: 3.50
FFS
P
C: 346
W: 744
W: 1701

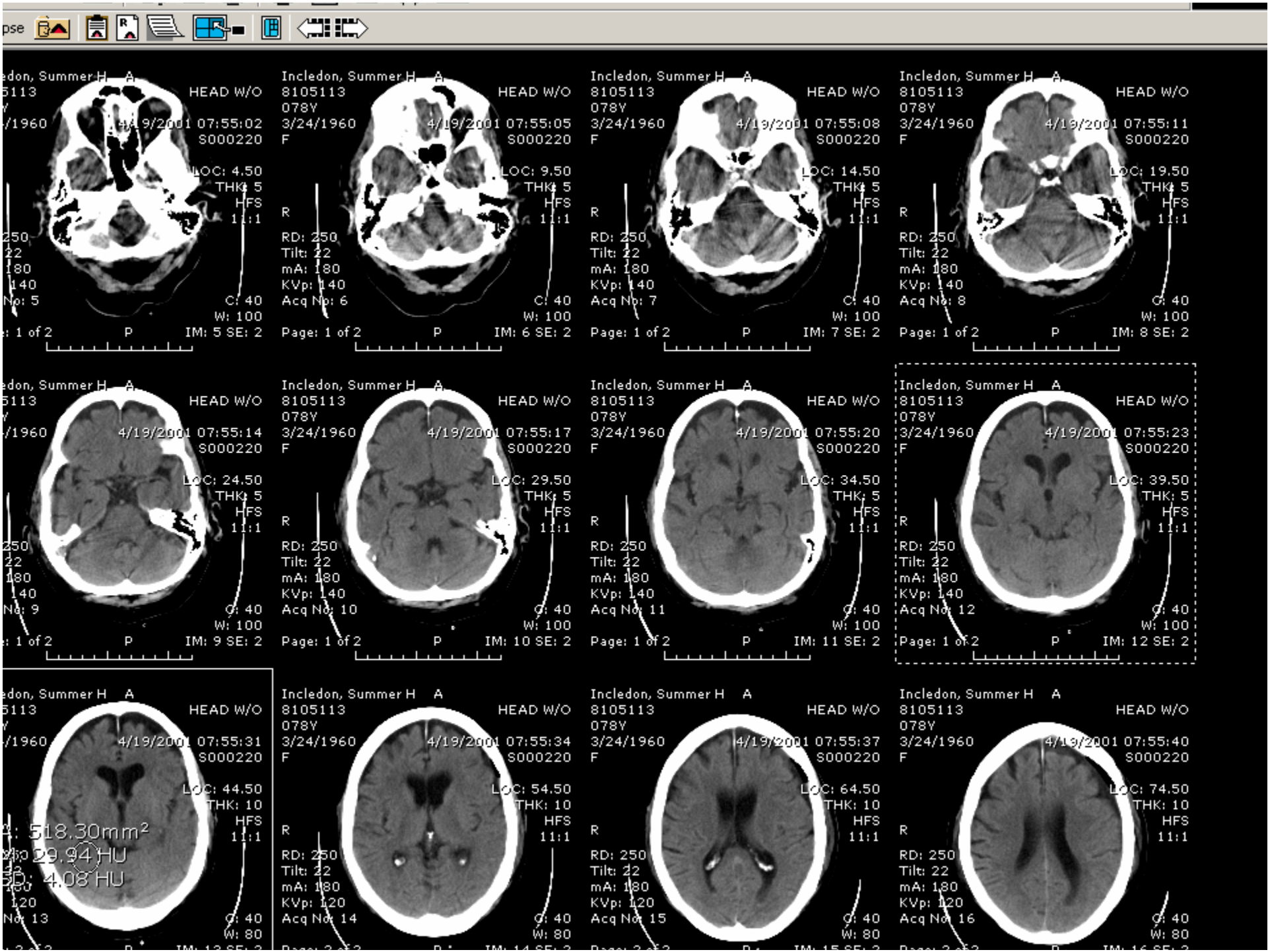
Knee MRI, showing multiple sequence hanging protocol and plane of interest function


dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 18:59:05
S000269
LOC: -31.13
THK: 10
FFS
P
E QUAD
20
10
4
C: 388
W: 806
IM: 1 SE: 2
: 1 of 3
Roundtree, Karen T
2131908
060Y
8/1/1963
F
A
RT. KNEE
5/30/2000 19:04:05
S000269
LOC: -7.14
THK: 4
FFS
L
R
KNEE QUAD
FE
FA: 35
TR: 660
TE: 15
C: 266
W: 618
Page: 1 of 15
45
25
1
M: 1 SE: 3
dtree, Karen T
1908
1963
H
RT. KNEE
5/30/2000 19:08:21
S000269
LOC: -36.28
THK: 4
FFS
L
E QUAD
90
2000
26
1
25
45
C: 913
W: 1701
Roundtree, Karen T
2131908
060Y
8/1/1963
F
H
RT. KNEE
5/30/2000 19:16:59
S000269
LOC: -27.12
THK: 3.50
FFS
A
P
KNEE QUAD
SE
FA: 90
TR: 2500
TE: 25
C: 389
W: 750

Head CT, showing area of interest function


edon, Summer H
5113
Y
4/1960
A
HEAD W/O
4/19/2001 07:55:31
S000220
LOC: 44.50
THK: 10
HFS
11:1
L
A: 518.30mm²
M: 29.94 HU
SD: 4.08 HU
250
22
180
120
No: 13
C: 40
W: 80
e: 13 of 23
P
IM: 13 SE: 2

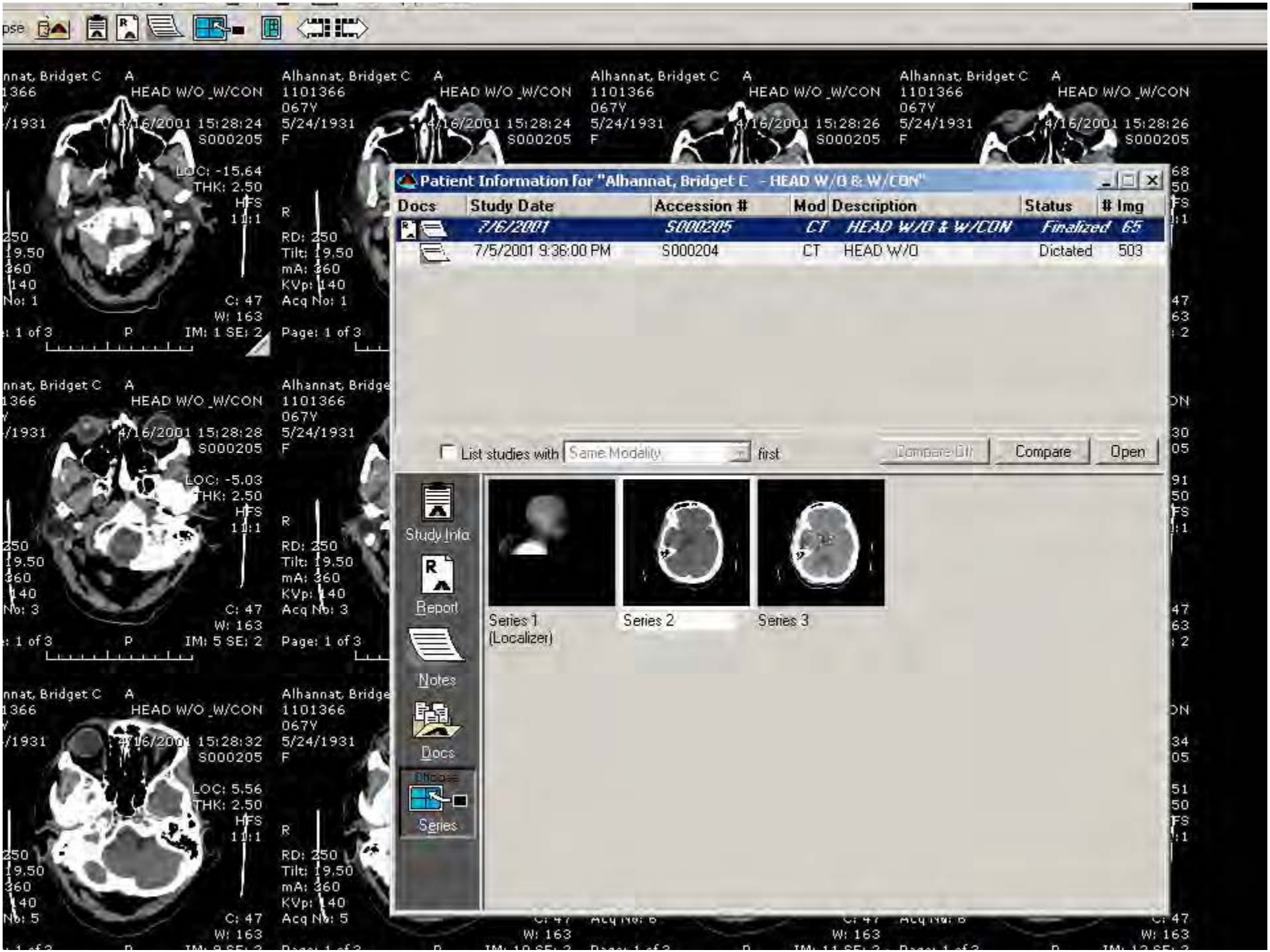
CT head, ‘tiling’ hanging protocol


Incledon, Summer H A
8105113
078Y
3/24/1960
F
HEAD W/O
4/19/2001 07:55:02
S000220
LOC: 4.50
THK: 5
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 140
Acq No: 5
C: 40
W: 100
Page: 1 of 2
P
IM: 5 SE: 2
4/19/2001 07:55:05
LOC: 9.50
Acq No: 6
IM: 6 SE: 2
4/19/2001 07:55:08
LOC: 14.50
Acq No: 7
IM: 7 SE: 2
4/19/2001 07:55:11
LOC: 19.50
Acq No: 8
IM: 8 SE: 2
4/19/2001 07:55:14
LOC: 24.50
Acq No: 9
IM: 9 SE: 2
4/19/2001 07:55:17
LOC: 29.50
Acq No: 10
IM: 10 SE: 2
4/19/2001 07:55:20
LOC: 34.50
Acq No: 11
IM: 11 SE: 2
4/19/2001 07:55:23
LOC: 39.50
Acq No: 12
IM: 12 SE: 2
4/19/2001 07:55:31
LOC: 44.50
THK: 10
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 120
Acq No: 13
C: 40
W: 80
518.30mm²
29.94 HU
4.08 HU
4/19/2001 07:55:34
LOC: 54.50
Acq No: 14
4/19/2001 07:55:37
LOC: 64.50
Acq No: 15
4/19/2001 07:55:40
LOC: 74.50
Acq No: 16

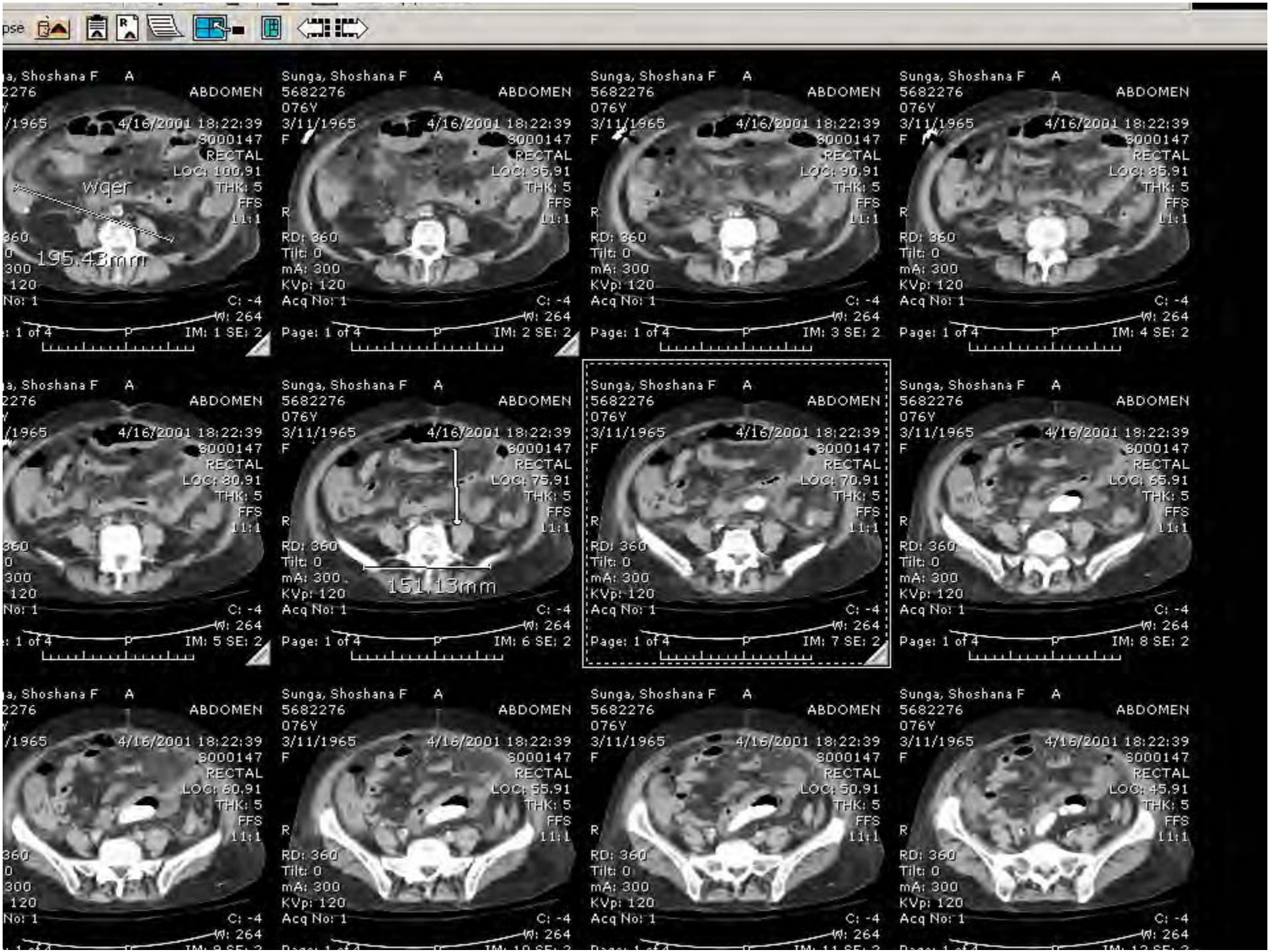
Head CT, showing pull down menu for choosing presets


Incledon, Summer H A
8105113
078Y
3/24/1960
F
HEAD W/O
4/19/2001 07:55:02
S000220
LOC: 4.50
THK: 5
HFS
11:1
RD: 250
Tilt: 22
mA: 180
KVp: 140
Acq No: 5
C: 50
W: 150
Page: 1 of 2
P
IM: 5 SE: 2
4/19/2001 07:55:05
LOC: 9.50
Acq No: 6
IM: 6 SE: 2
4/19/2001 07:55:08
LOC: 14.50
Acq No: 7
IM: 8 SE: 2
4/19/2001 07:55:11
LOC: 19.50
4/19/2001 07:55:14
LOC: 24.50
Acq No: 9
IM: 9 SE: 2
4/19/2001 07:55:17
LOC: 29.50
Acq No: 10
IM: 10 SE: 2
4/19/2001 07:55:23
LOC: 39.50
Acq No: 11
4/19/2001 07:55:31
LOC: 44.50
THK: 10
Acq No: 13
4/19/2001 07:55:34
LOC: 54.50
Acq No: 14
4/19/2001 07:55:40
LOC: 74.50
Acq No: 16
Window Level
Zoom
Pan
Ruler R
Text T
Arrow A
Density Value D
Lock Tools L
Image Presets
Scale, Rotate, Flip
Tools
Reference Lines
Apply Tools
Save Image
AON Factor
Copy To Clipboard
Tile Formats
IntelliLink I
IntelliScroll S
IntelliScroll Add/Remove K
IntelliScroll - Remove All C
Cine...
Print...
Bone NUMPAD 0
Abdomen NUMPAD 1
Lung NUMPAD 2
BRAIN NUMPAD 3
Liver NUMPAD 5
Spines NUMPAD 4
Scout NUMPAD 6
Revert NUMPAD 9
Invert

CT head, showing menu for choosing image series


Alhannat, Bridget C A
1101366
HEAD W/O _W/CON
067Y
5/24/1931
F
4/16/2001 15:28:24
S000205
LOC: -15.64
THK: 2.50
HFS
11:1
RD: 250
Tilt: 19.50
mA: 360
KVp: 140
Acq No: 1
C: 47
W: 163
Page: 1 of 3
Patient Information for "Alhannat, Bridget C - HEAD W/O & W/CON"
Docs
Study Date
Accession #
Mod
Description
Status
# Img
7/6/2001
S000205
CT
HEAD W/O & W/CON
Finalized
65
7/5/2001 9:36:00 PM
S000204
CT
HEAD W/O
Dictated
503
List studies with
Same Modality
first
Compare Dif
Compare
Open
Study Info
Report
Notes
Docs
Series
Series 1
(Localizer)
Series 2
Series 3

CT abdomen, ‘tiling’ hanging protocol


Sunga, Shoshana F A
5682276
076Y
3/11/1965 F
ABDOMEN
4/16/2001 18:22:39
S000147
RECTAL
LOC: 100.91
LOC: 95.91
LOC: 90.91
LOC: 85.91
LOC: 80.91
LOC: 75.91
LOC: 70.91
LOC: 65.91
LOC: 60.91
LOC: 55.91
LOC: 50.91
LOC: 45.91
THK: 5
FFS
11:1
R
RD: 360
Tilt: 0
mA: 300
KVp: 120
Acq No: 1
C: -4
W: 264
wqer
195.43mm
151.13mm
Page: 1 of 4
IM: 1 SE: 2
IM: 2 SE: 2
IM: 3 SE: 2
IM: 4 SE: 2
IM: 5 SE: 2
IM: 6 SE: 2
IM: 7 SE: 2
IM: 8 SE: 2

There is a reduction of 16.2% in the time taken to interpret CT scans with PACS vs film due to the improved software, optimized hanging protocols, preset window and level settings, faster image retrieval, ‘stack mode’ and ‘linked stack mode’ viewing.

Refs 36, 39

There was also an improvement in the sensitivity, specificity and overall accuracy for interpretations of chest, brain and chest/abdomen CT scans viewed with PACS vs hard copy film interpretations.

Ref 39

# Reasons for improved CT readings with PACS

- Use of workstation tools aids interpretation
- Use of stack mode to view images

Ref 39

# Paradigm shift in viewing techniques

- Multiple viewboxes vs one or two monitors
- Use bright light vs change contrast function on workstation
- Hold film vs hold mouse

# Paradigm shift cont'd

- Use hand held magnifying glass vs use magnify function on workstation
- Measure distances and angles with ruler and goniometer vs measure distances and angles with measuring functions on workstation

# Paradigm shift cont'd

- Draw on image with wax pencil vs annotate image using keyboard and / or draw function on workstation
- Remove film from jacket for future use vs access images from office or home PC via secure internet connection and / or burn a CD

# Paradigm shift cont'd

- Search through folder for the previous films vs previous studies automatically displayed along with the current study

# Viewing habits

- Early on, people tend to use ‘tile mode’ for viewing CT’s. This reflects their experience with hard copy film.
- After using PACS for a while, most people view CT’s in ‘stack mode’
- Interpretation of CT’s is more rapid when viewed in ‘stack mode’

Ref 25

# Conclusion

PACS requires a change in the way we view images, but provides improved workflow, improved throughput, improved accessibility to images, ability to manipulate images, and improved communication capability, all geared to the goal of improving patient care.

Robert H. Posteraro, M.D.
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# PACS for Technologists

Picture
Archiving and
Communications
System

PACS

# Digital image acquisition, storage and transmission

PACS differs
from
film based radiography

# PACS affects

- Radiologists
- Radiological technologists
- Clinicians
- Nurses
- Hospital administrators
- Film filing personnel

Problems of early digital imaging:

Multiple vendors +
Proprietary systems
= Incompatibility

# Enter DICOM

Digital Imaging and Communications in Medicine

DICOM is based on the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) standard

DICOM standardized communications protocols for image and image identification data so that equipment items from different vendors could communicate with each other.
It is a non-proprietary, open architecture standard.

# Open architecture - RADICAL CONCEPT!

Different pieces of equipment could communicate with each other, and could share the same patient demographic data from the hospital information system (HIS) or radiology information system (RIS),

- IF -

all the pieces of equipment were DICOM compatible.

# What catalyzed PACS?

- Increased number of studies ordered
- Increased number of images per study
- Increased use of personal computers

# Advantages of PACS for technologists

- No lost films
- Images can be manipulated
- Decreased repeat rate
- No loss of resolution when images are copied

# Technical limitations of early PACS

- Computer equipment was expensive
- Computer memory was limited
- Storage memory was expensive and limited

# More limitations …

- Images files are large
- Transmission times were SLOW

# And still more limitations …

- High resolution monitors were expensive
- Limited image manipulation functions
- Not user friendly

# Administrative limitations

- No positive financial return for the institution
- What if we are the ‘only show in town’?
- Fear of obsolescence

# Enter …

- Less expensive computers and monitors
- Less expensive memory
- More user friendly software (GUI)
- More standardized controls (icons)

PACS becomes more feasible

The first institutions to install PACS were governmental institutions (military and Veterans Administration facilities)

Reliable source of funding

Relatively stable patient population

# PACS workflow

- Technologist acquires images
- Technologist approves images
- Transmission of images to storage
- Study appears on work list
- Retrieval of images from storage
- Interpretation of images

# Technologist productivity

10.8% reduction in productivity in the first year after PACS installation

27.8 increase in productivity beyond the first year after PACS installation

Ref 1

Most of the increase in productivity is in the multi imaging studies (CT, MRI, ultrasound)

Ref 2

# Technologist productivity has increased with PACS

- MRI 58%
- CT 30%
- Ultrasound 41%

Ref 7

70% decrease in time for images to be available with PACS vs conventional film imaging

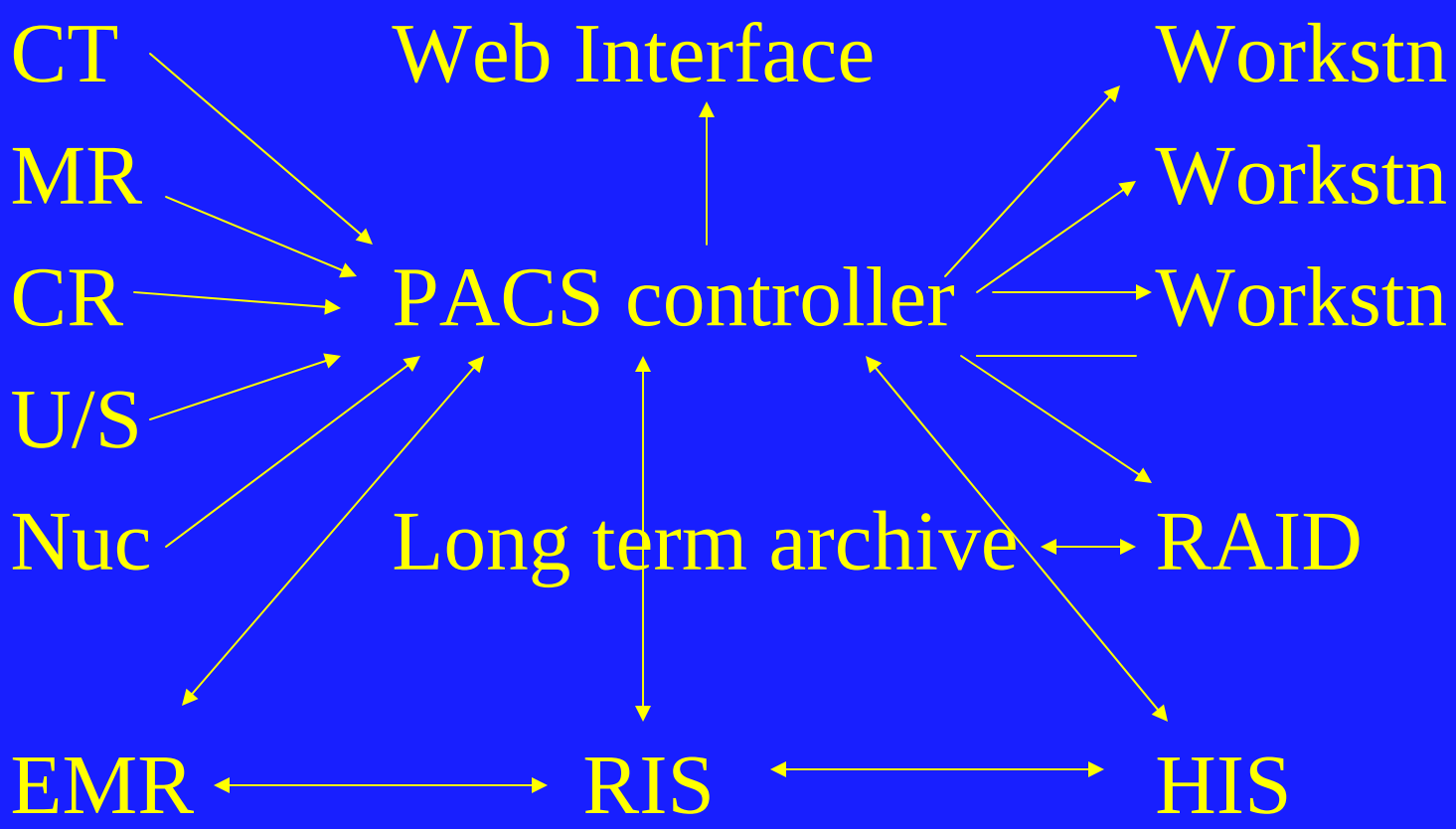
Ref 12

# Average time for chest image to be available

- 14.4 minutes from time the first image is taken (range 4 - 49 minutes) for PACS vs
- 47.9 minutes (range 18 - 85 minutes) for conventional film image

Ref 12

# The complexity of PACS



All components must function seamlessly

# Order of events in PACS

1. The modality acquires the images
2. The DICOM gateway receives images from the modality
3. The DICOM gateway verifies the image format and reformats the images to DICOM format if necessary
4. The DICOM gateway transmits the images to the PACS controller

Ref 13

# Order of events cont'd

5. The DICOM gateway verifies that the images have been transmitted successfully
6. If the PACS controller fails to receive the images, the DICOM gateway retains the images until the PACS controller receives them successfully

Ref 13

# PACS controller

- Receives and archives the DICOM images
- Is responsible for automatic or on-demand distribution of the images to the viewing workstations
- Transmits the images to the long term archive (RAID)

Ref 13

# Viewing Workstation

- Receives the images
- Presents the images for viewing
- Has image processor functions available

Ref 13

# RAID

- Stands for ‘Redundant Array of Inexpensive Disks’
- Is the long term archive
- Stores the images indefinitely

Ref 13

Technologists reported lower levels of stress and fatigue after PACS installation, in spite of an increased work load.

Ref 1

# Integrating the Healthcare Environment (IHE)

- Began in 1998 with the goal to encourage integration of information systems with the healthcare enterprise
- Data integration with the aim of improving workflow and information sharing in support of better patient care

Ref 13

PACS is a component of IHE

# The other components of IHE are

- Hospital information system (HIS)
- Radiology information system (RIS)
- Electronic medical record (EMR)
- Telemedicine network
- Web based health care networks

Ref 13

# Conclusion

The increased demands of patient care, technological advancements and the increased expectations of clinicians have resulted in an increase in the workload of radiological technologists. This increased workload can be handled most effectively by applying the improved image handling technology of PACS.

Robert H. Posteraro, M.D.
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# The technology of PACS

Picture
Archiving and
Communications
System

PACS

# Digital image acquisition, storage and transmission

Problems of early digital imaging:

Multiple vendors +
Proprietary systems
= Incompatibility

# Enter DICOM

Digital Imaging and Communications in Medicine

DICOM is based on the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) standard

# ACR-NEMA standard

- 1983 Established
- 1985 ACR-NEMA standard v1.0
- 1988 v2.0
- 1993 DICOM v3.0
- Continuous evolution

Ref 11

DICOM standardized communications protocols for image and image identification data so that equipment items from different vendors could communicate with each other.
It is a non-proprietary, open architecture standard.

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- Storage memory was expensive and limited

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- Transmission times were SLOW

# And still more limitations …

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- Limited image manipulation functions
- Not user friendly

# Enter …

- Less expensive computers and monitors
- Less expensive memory
- More user friendly software (GUI)
- More standardized controls (icons)

PACS becomes more feasible

# PACS workflow

- Technologist acquires images
- Technologist approves images
- Transmission of images to storage
- Study appears on work list
- Retrieval of images from storage
- Interpretation of images

# Workstations

- High resolution monitors (‘standard’ is 2 megapixels, but can be up to 4 megapixels)
- Increased resolution --> increased cost
- 1, 2, 4 or 8 monitors?

# Workstation functions

- Change contrast
- Invert gray scale
- Flip
- Rotate
- Magnify

# Workstation functions cont'd …

- Pan
- Zoom
- Measure
  - Linear distance, area, angle, density

# Workstation functions cont'd …

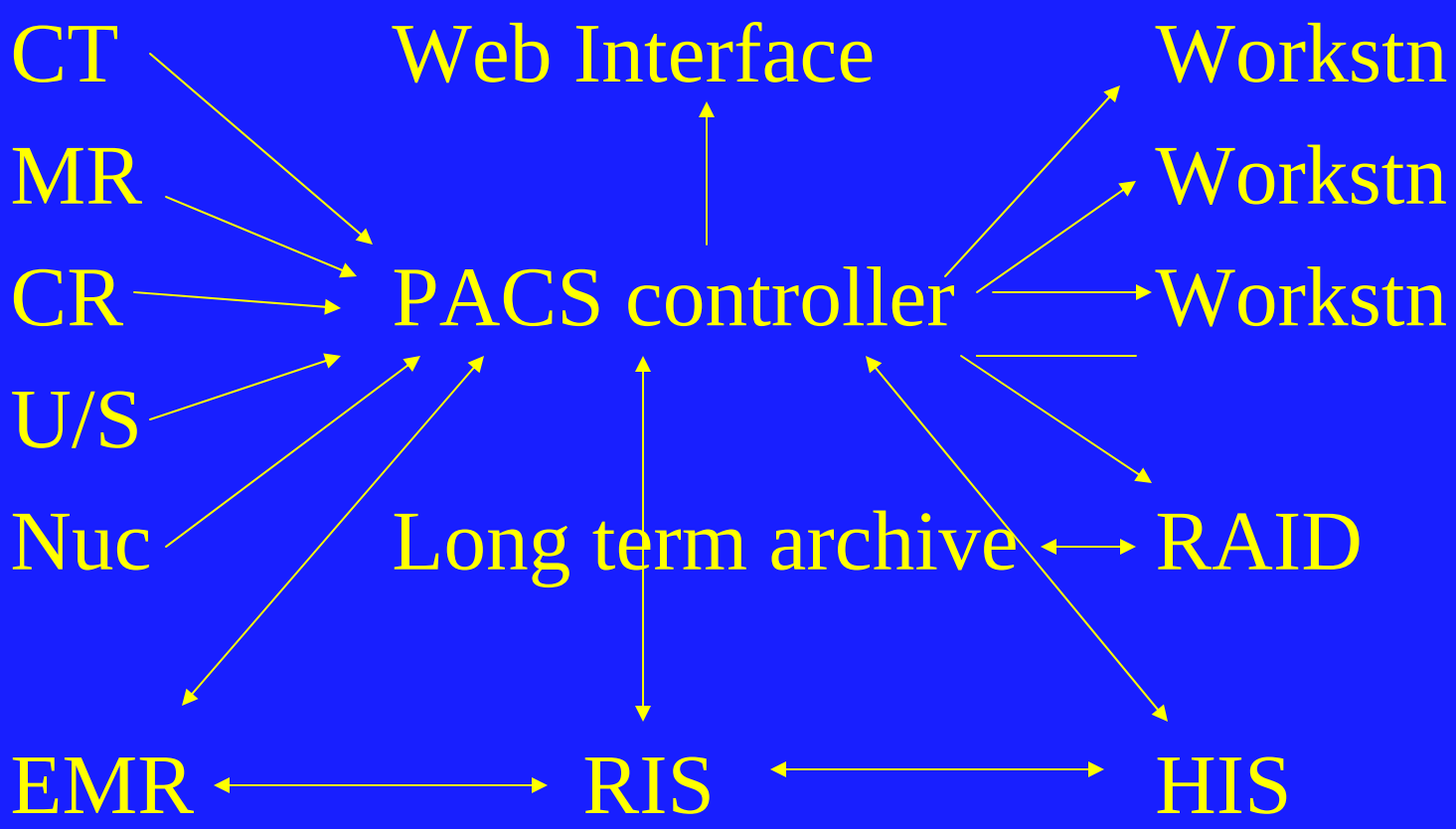
- Set individual preferences
- Choice of hanging protocols
- Automatic retrieval of comparison images

# Web access to images and reports

- Secure socket layer (SSL) guarantees integrity of data and confidentiality between client and server
- 128 bit encryption
- Ensure that the user has access only to data that he/she actually needs

Ref 9

# The complexity of PACS



All components must function seamlessly

# Order of events in PACS

1. The modality acquires the images
2. The DICOM gateway receives images from the modality
3. The DICOM gateway verifies the image format and reformats the images to DICOM format if necessary
4. The DICOM gateway transmits the images to the PACS controller

Ref 13

# Order of events cont'd

5. The DICOM gateway verifies that the images have been transmitted successfully
6. If the PACS controller fails to receive the images, the DICOM gateway retains the images until the PACS controller receives them successfully

Ref 13

# PACS controller

- Receives and archives the DICOM images
- Is responsible for automatic or on-demand distribution of the images to the viewing workstations
- Transmits the images to the long term archive (RAID)

Ref 13

# Viewing Workstation

- Receives the images
- Presents the images for viewing
- Has image processor functions available

Ref 13

# RAID

- Stands for ‘Redundant Array of Inexpensive Disks’
- Is the long term archive
- Stores the images indefinitely

Ref 13

# PACS storage requirements

On the order of several terabytes per year for an average sized hospital

Ref 14

Kilo 1,000

Mega 1,000,000

Giga 1,000,000,000

Tera 1,000,000,000,000

# Image compression

- Lossy compression - data is lost when the image is compressed
- Lossless compression - no data is lost when the image is compressed
- Image files can be compressed up to 20:1 without loss of data
- Compression of images saves storage space and also permits faster transmission of images

# Copy images

- Convert to hard copy (film) - durable, expensive
- Paper copies - inexpensive, not durable
- CD-ROM or DVD
  - Can be viewed on any PC
  - The disk includes the application software for viewing (don’t need to purchase special software)

# The Economics of PACS

- Higher fixed costs
  - Hardware, networking, storage media
- Lower variable costs
  - No film, no processor chemicals

# Economics cont'd - Personnel

- Personnel costs with PACS
  - Fewer (if any) file room personnel
  - More information systems (IS) personnel
- Net result is break even or some increased cost with PACS

# Economics cont’d - Space

- Decreased film storage space requirements
- Increased space for hardware
- Net result - large savings in space

# Economics cont'd - Indirect costs

- Decreased time of exams
- Markedly decreased repeat exam rate
- 'No' lost films
- Decreased turnaround time
- More rapid decision making by clinicians

# How many monitors are enough?

- Ohio State University, 3 hospitals and outpatient imaging facility
- 250,000 exams per year
- 26 radiologists and 10 experienced residents interviewed (54% had had experience with 4 monitor workstations)

Ref 25

# How many monitors? Plain films

- 18 radiologists
  - 56% used 2 monitors
  - 44% used 1 monitor
- 10 residents
  - 80% used 2 monitors
  - 20% used 1 monitor

Ref 25

# How many monitors? CT

- 24 radiologists
  - 17% used 1 monitor with 4 on 1 display
  - 8% used 2 monitors with 4 on 1 display
  - 54% used 1 on 1 ‘stack mode’ viewing
  - 21% used combinations of the above
- 10 residents
  - 100% used 1 on 1 ‘stack mode’ viewing

Ref 25

# How many monitors? U/S

- 8 radiologists
  - 76% used 1 monitor with 4 or fewer images
  - 12% used 2 monitors
  - 12% used 1 on 1 ‘stack mode’ viewing
- 10 residents
  - 33% used 1 on 1 ‘stack mode’ viewing
  - 67% used 1 monitor with 4 or fewer images

Ref 25

# How many monitors? MRI

- 19 radiologists
  - 37% viewed 4 separate sequences on 1 monitor
  - 71% used 2 monitors if more than 4 sequences in the study
  - 42% viewed each sequence 1 on 1 on 1 monitor
  - 5% viewed 2 series on 1 monitor
  - 15% used a combination

Ref 25

# How many monitors? MRI cont'd

- 9 residents
  - 67% viewed 4 series on 1 monior
  - 20% viewed the study 1 on 1 on 1 monitor
  - 10% viewed 2 series on 1 monitor

Ref 25

# How many monitors? Angio

- All viewed the studies 1 on 1. The second monitor was used for comparison studies.

Ref 25

How many monitors?

# Before PACS

- 31% of radiologists felt that 2 monitors would be adequate
- 23% felt that 2 monitors would be needed for plain film imaging, but 4 monitors would be needed for cross sectional imaging
- 27% felt that 4 monitors would be needed for both
- 19% felt that more than 4 monitors would be needed

Ref 25

# After PACS

- 88% felt that 2 monitors were enough for plain film images and cross sectional images
- 96% felt that fewer monitors were needed than they had previously thought
- 85% said that they preferred using 2 monitors rather than 4

Ref 25

# Portability of images

- CD-ROM storage 640 Mb of data
  - 12 - 30 CT exams
  - 24 - 80 MRI exams
  - 60 - 128 ultrasound exams
  - 32 - 64 computed radiographic exams (‘plain film images’)
  - 80 digitized radiographs
  - 5 digitized mammograms

Ref 30

# Cost of copies

- CD-ROM 2 to 4 dollars, stores numerous images
- Hard copy film 10 to 20 dollars per sheet (includes technical costs)

Ref 30

# File Size of Exams

| Exam | Dimension | Gray level | # images | Size |
|---|---|---|---|---|
| | (pixels) | (bits) | | (Mbytes) |
| CT | 512 x 512 | 12 | 70 | 36.7 |
| MRI | 256 x 256 | 12 | 150 | 19.7 |
| U/S | 512 x 512 | 8 | 30 | 7.8 |
| CR | 2,048 x 2,048 | 12 | 2 | 16.7 |
| DR | 2,048 x 2,048 | 12 | 2 | 16.7 |

Ref 30

Necessary to integrate PACS with the hospital information system, transcription and the electronic medical record in order to maximize efficiency.

Ref 31

# Transmission speeds

| Modality | Maximum bandwidth | Transmission speed for 1Mb | Transmission time for 80 Mb exam |
|---|---|---|---|
| Modem | 56 kb/s | 142.8 sec (2.4 min) | 11,489 sec (190 min) |
| ISDN | 128 kb/s | 62.5 sec | 5,000 sec (83.3 min) |
| DSL | 384 kb/s | 20.8 sec | 1,667 sec (27.8 min) |

Ref 32

# Transmission speeds cont'd

| Modality | Maximum bandwidth | Transmission speed for 1 Mb | Transmission speed for 80 Mb exam |
|---|---|---|---|
| Ethernet | 10 Mb/s | 0.8 sec | 64 sec |
| Fast ethernet | 100 Mb/s | 0.08 sec | 6.4 sec |

Ref 32

# Transmission speeds cont'd

| Modality | Maximum bandwidth | Transmission speed for 1 Mb | Transmission speed for 80 Mb exam |
|---|---|---|---|
| Gigabit ethernet | 1,000 Mb/s | 0.008 sec | 0.64 sec |
| ATM | 155 Mb/s | 0.52 sec | 4.1 sec |
| Fast ether 10:1 comp | 100 Mb/s | 0.008 sec | 0.64 sec |

Ref 32

# Security - 2 categories

- Access security - protection of computer systems against access by unauthorized persons
- Data security - protection of data transmission against electronic eavesdropping, content alteration or faking the identity of the sender

Ref 41

# Conclusion

- PACS has revolutionized medical imaging.
- It involves new technology that must be learned and understood.
- At the present time it is the only way by which we can efficiently and effectively handle the vast quantities of imaging data that we are generating.

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