# Patient Peripheral Dose Resulting from IGRT Procedures

**James M. Galvin, DSc**

**Thomas Jefferson University Hospital**

**Jefferson Medical College**

**Philadelphia, PA**

**and**

**The Radiation Therapy Oncology Group**

# Definition of Image Guided Radiation Therapy

- Process extending from CT-simulation imaging through the step of imaging the patient on the treatment unit
  - Process includes the following steps:
    - Manual or automatic registration of the two datasets
    - Determination of a series of mechanical movements of the patient support system to correct for detected positioning errors

# Older Techniques of Verifying Patient Position

- Radiographic Film
- Electronic Portal Imaging Device (EPID)
- Simulation Radiographs
- Virtual Simulation CT Imaging

# The Electronic Portal Imaging Device (EPID)

# Reason for Increased Peripheral Dose for Radiation Therapy Patients

- **Intensity Modulated Radiation Therapy (IMRT)**
  - Increased leakage radiation
- **Increased Planning dose**
  - CT scanning in general
  - 4D CT Planning in particular
- **Increased Imaging as Part of Daily Treatment**
  - New technologies are easy and helpful to use daily

# Increased Treatment Planning Dose

**A 4D CT scan is equal to approximately 3 conventional CT studies!**

# Major Change with IGRT

**We are moving from weekly imaging to daily imaging!**

# Increased Imaging as Part of Daily Treatment

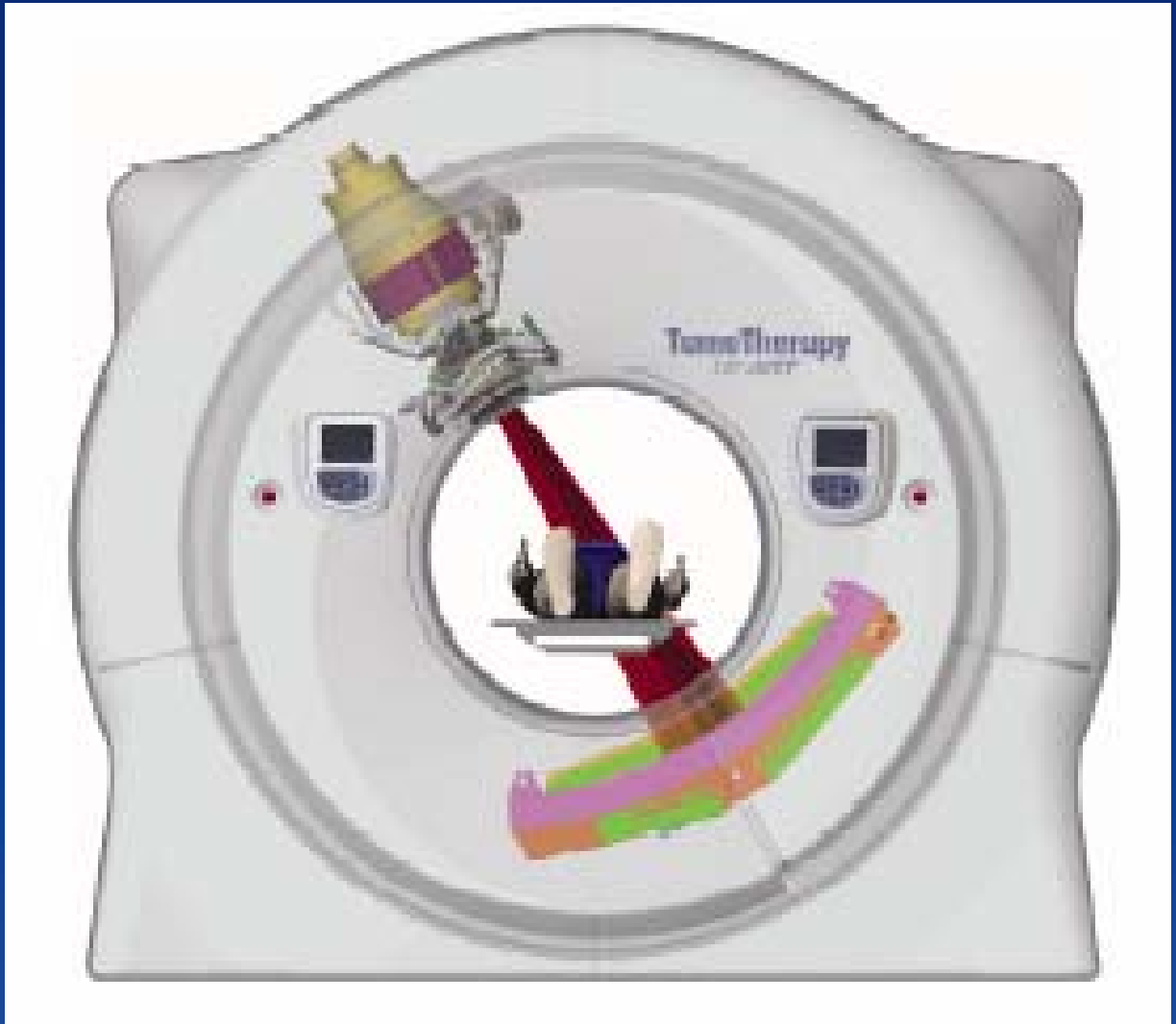
- This is our topic for today's talk
- Radiation treatments are usually “fractionated”
- This trend could change with recent interest in “hypo-fractionated” treatment

# IGRT Techniques

- In-room diagnostic quality CT scanner
- MV and kV cone-beam CT attachments
- MV helical CT capabilities
- Stereoscopic 2D images obtained with MV or kV x-rays

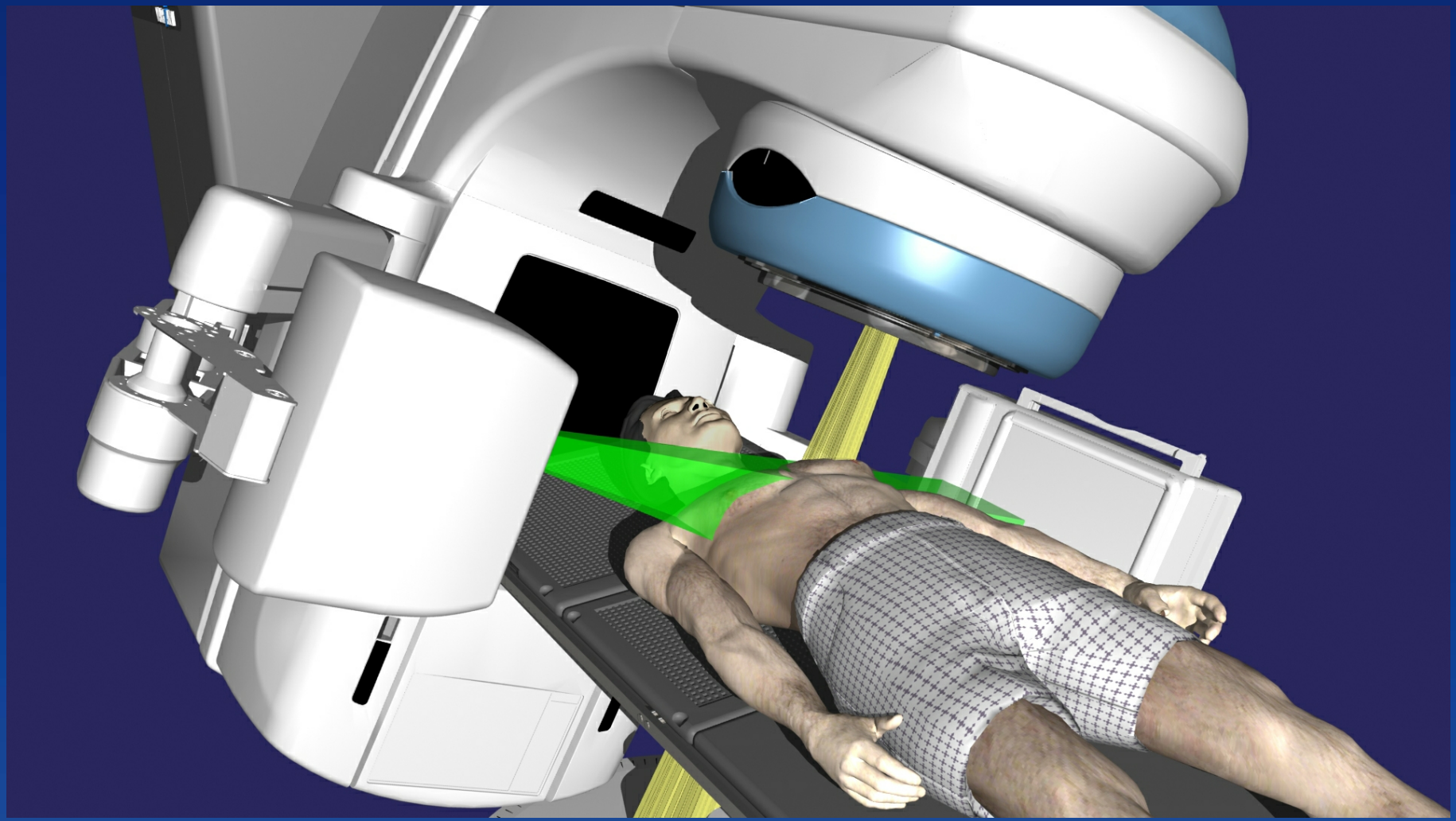
# Elekta Synergy Cone-beam System

# TomoTherapy Hi-Art Unit



# Varian Cone-Beam CT with Robotic Arms

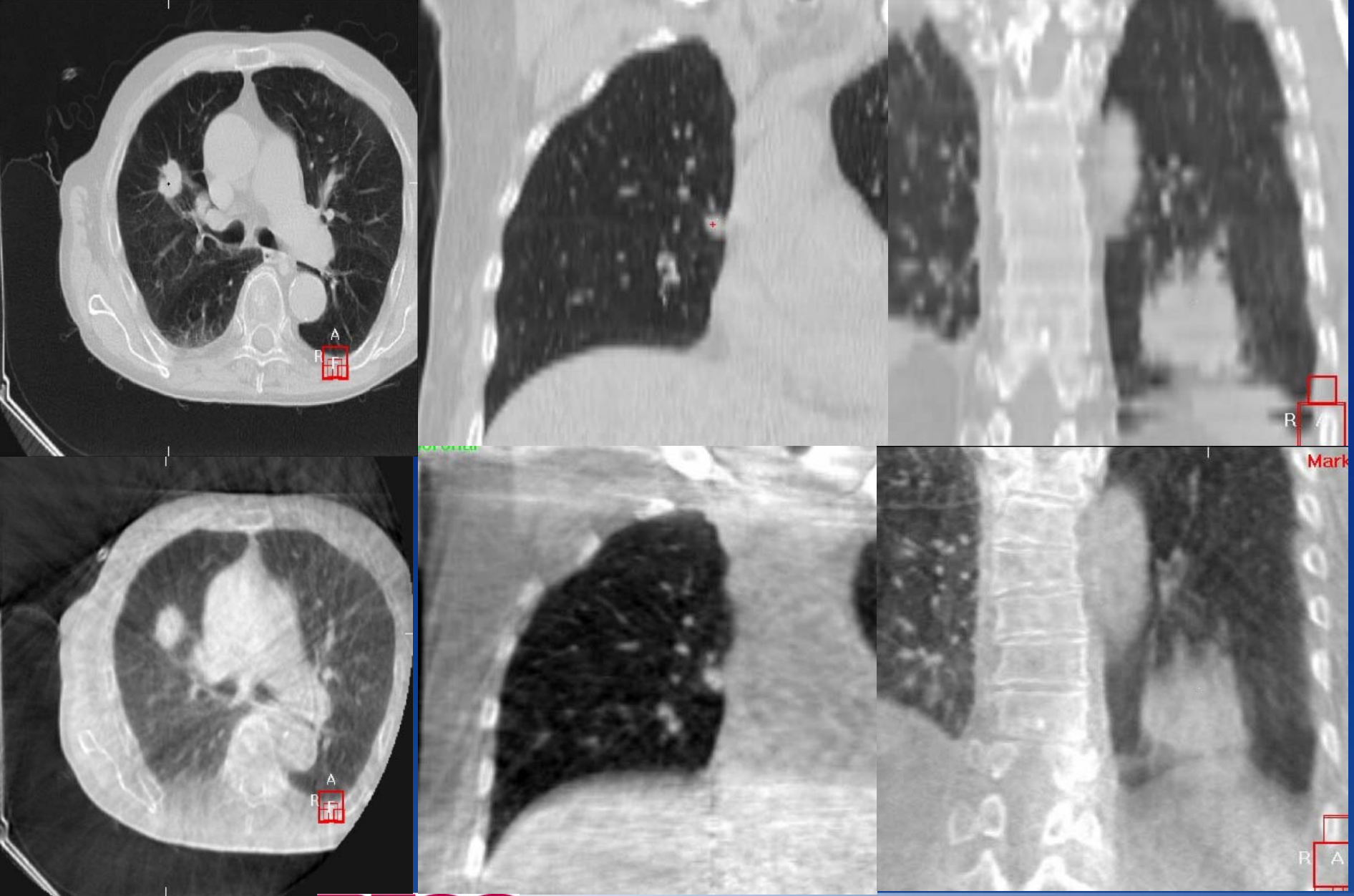
# Varian On-Board Imaging Device



# Different IGRT Approaches

- There are many different ways of imaging the patient in the treatment room
  - MV and kV
  - Planar, Volume and Helical Scanning

# Elekta Cone-Beam CT



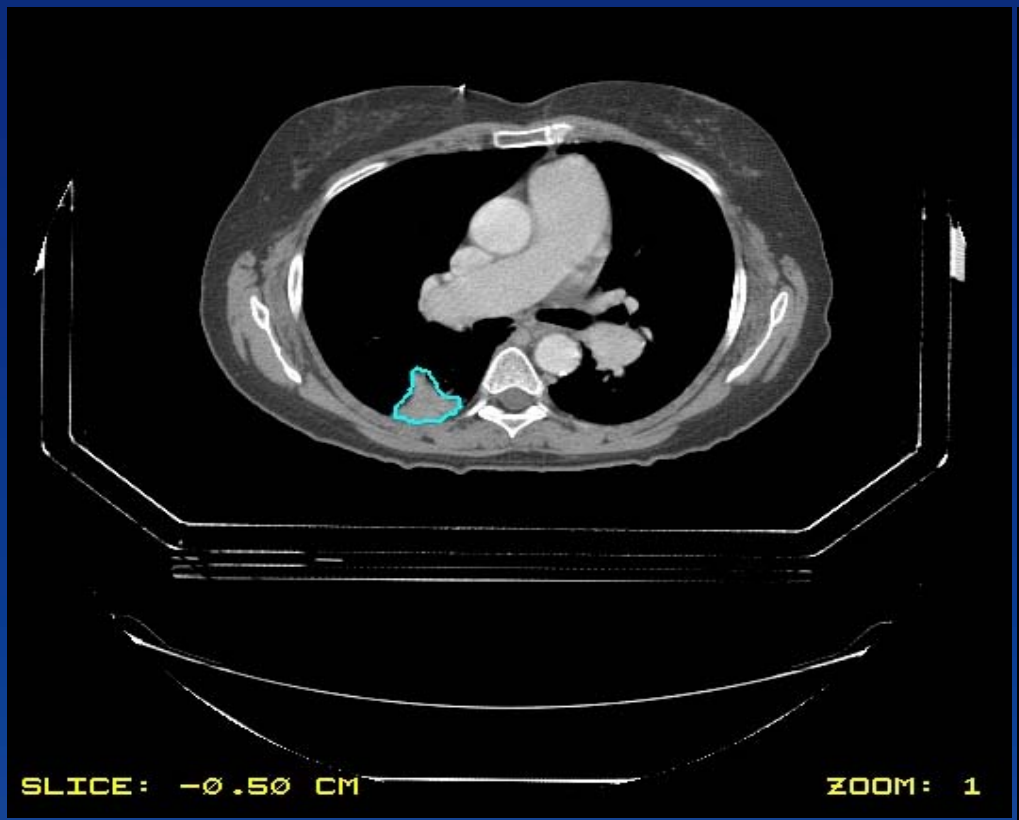
CT-Sim

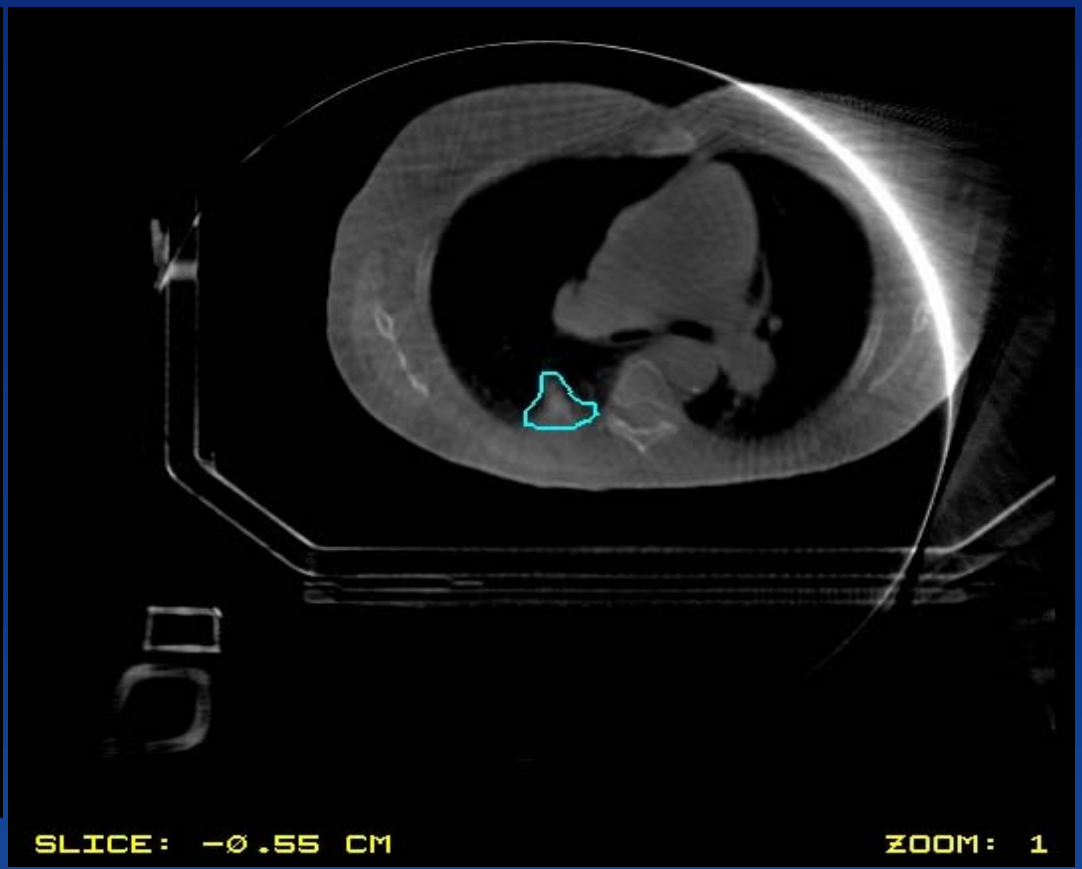
CB CT

Jefferson

RTOG
Radiation Therapy Oncology Group

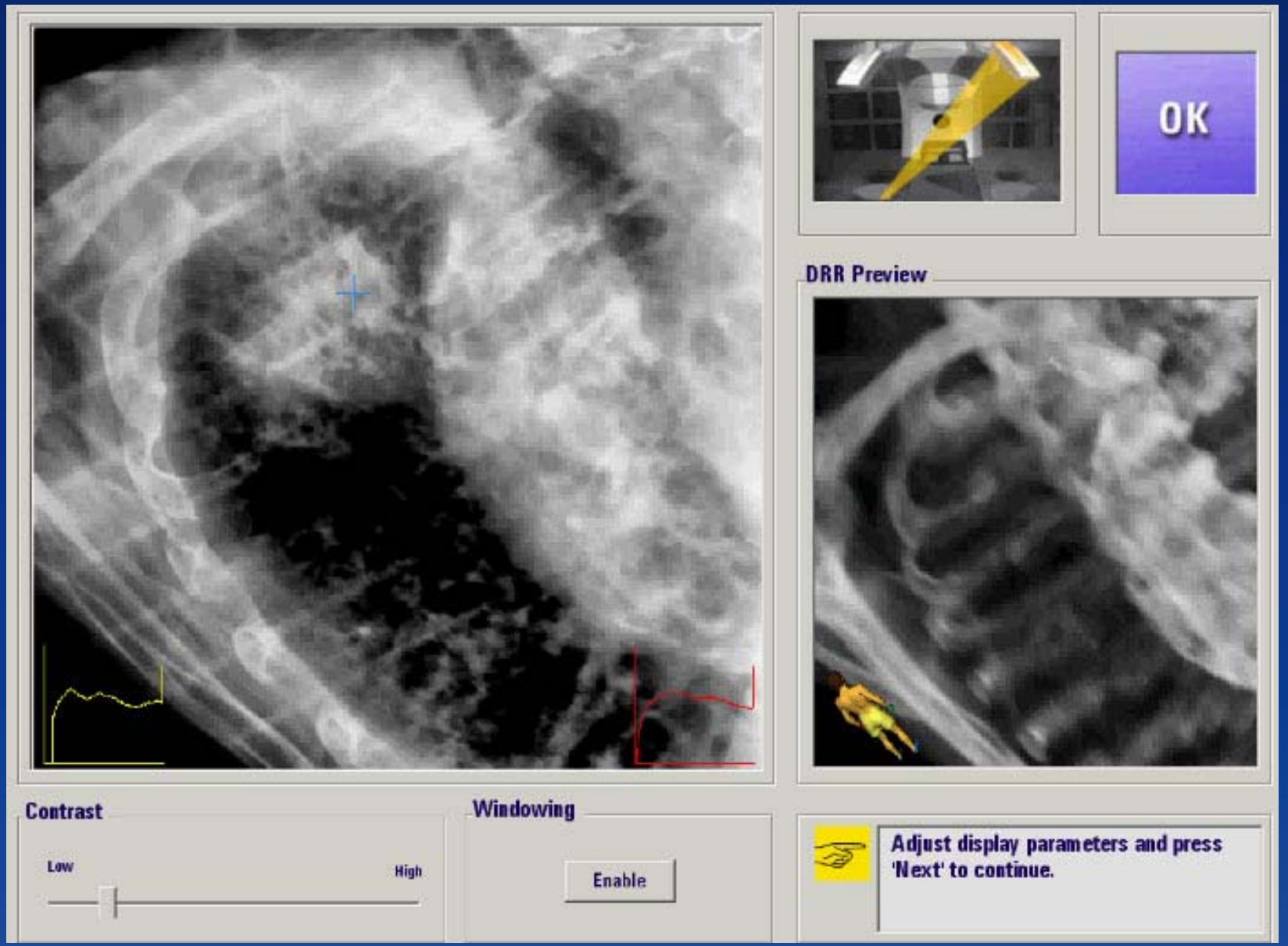
# ITC Remote Review Tool

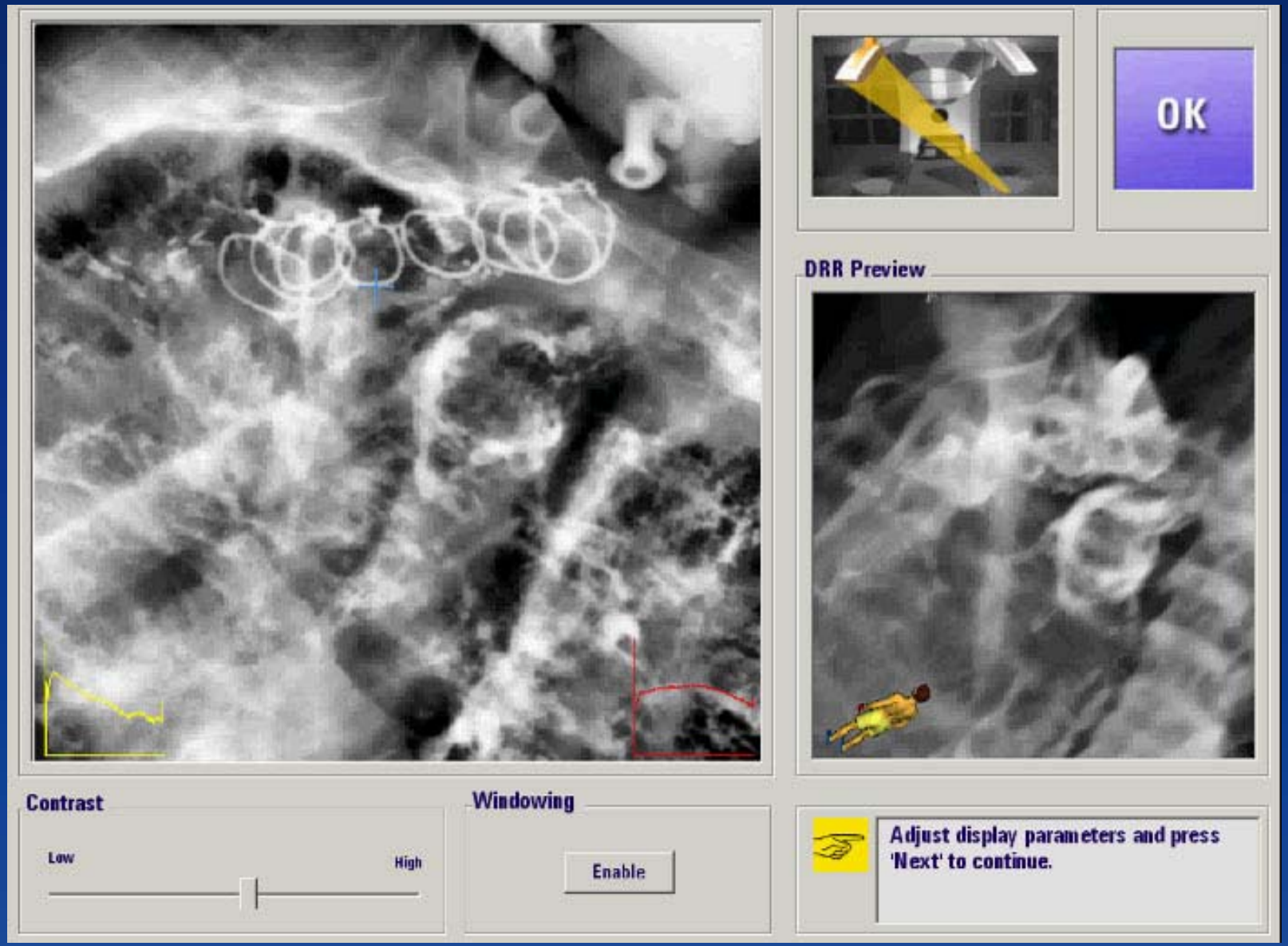


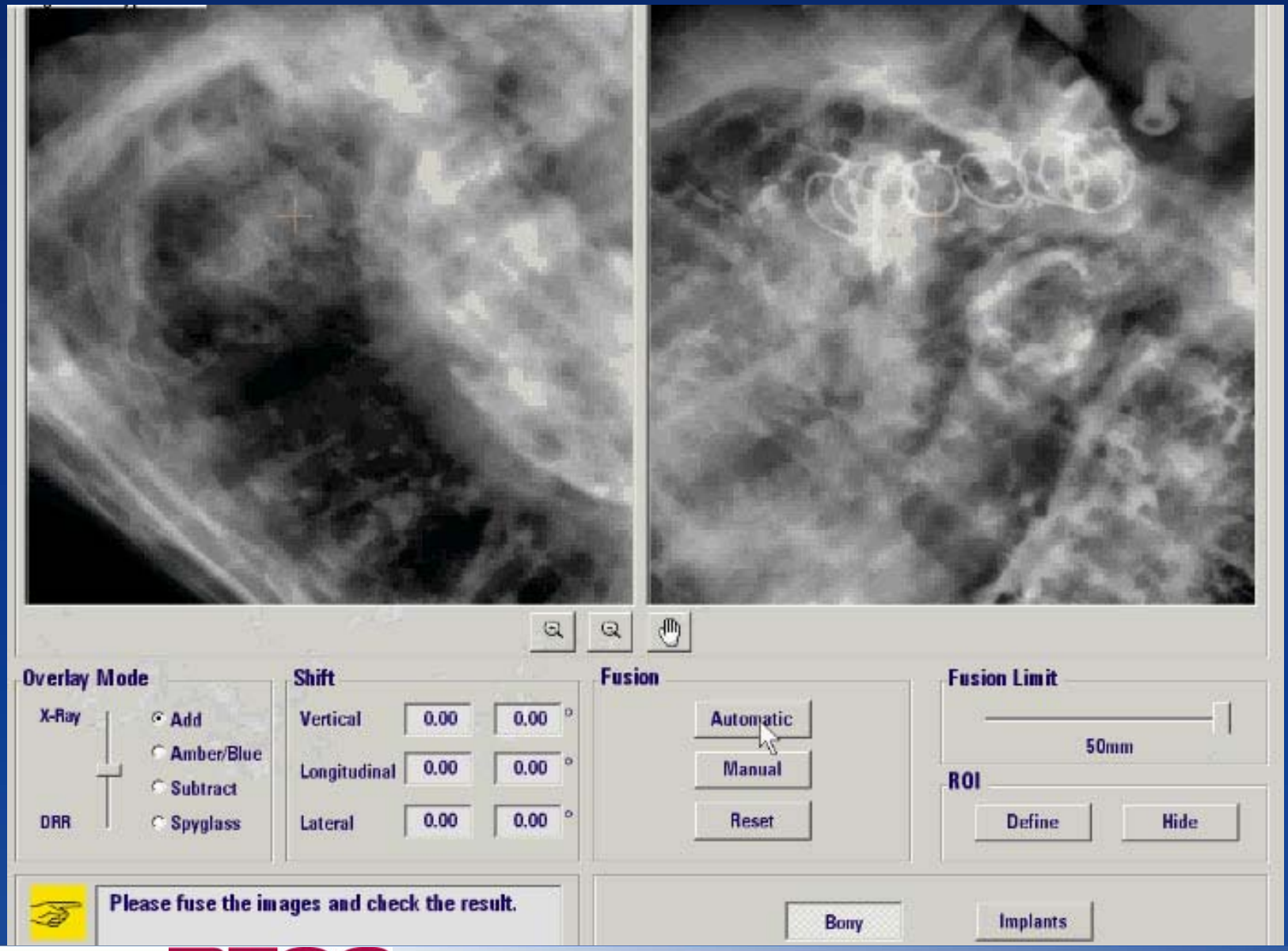



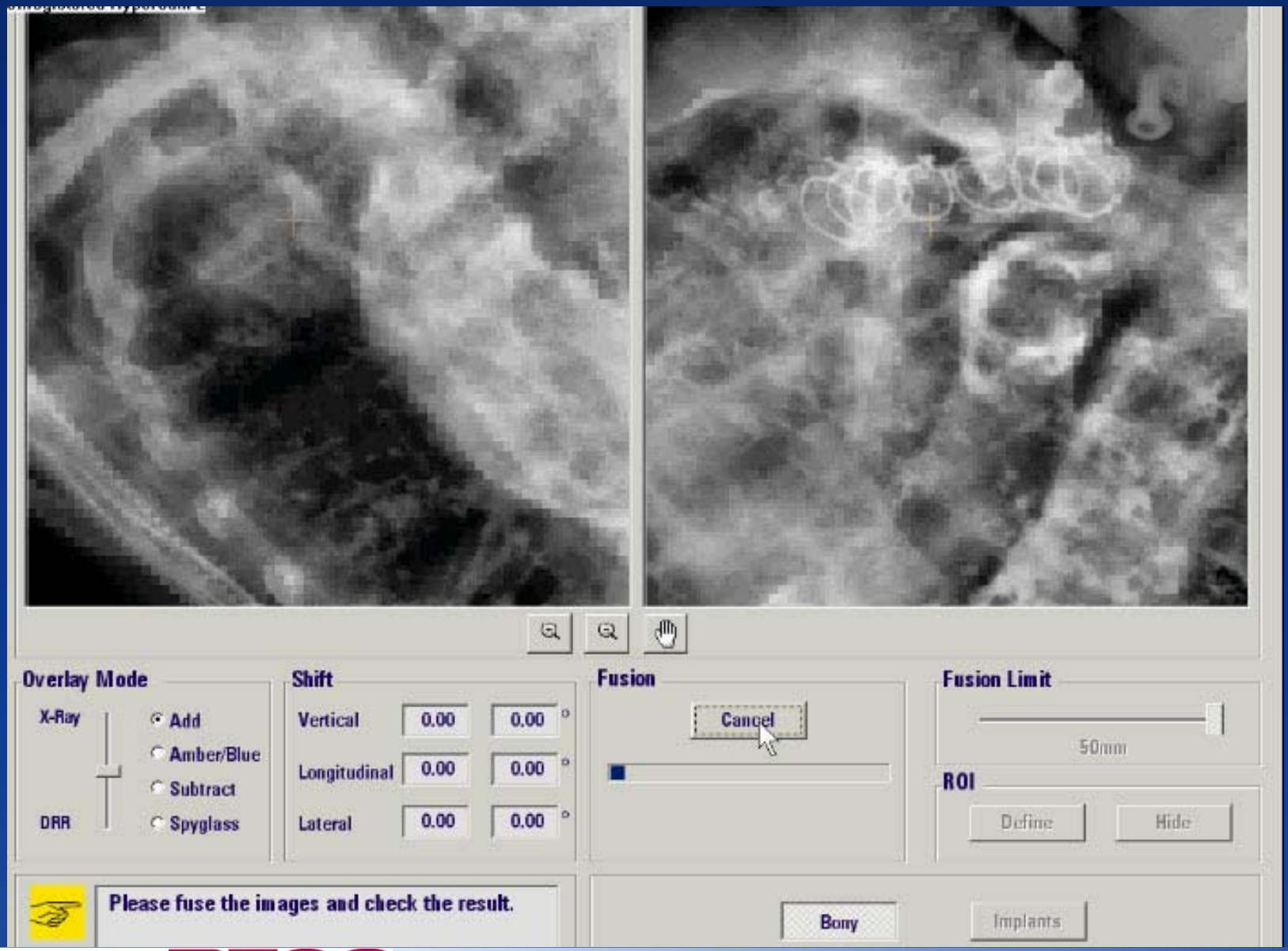
BrainLAB Novalis System with ExacTrac Imaging – dual x-ray tubes and a-Si panels create orthogonal images

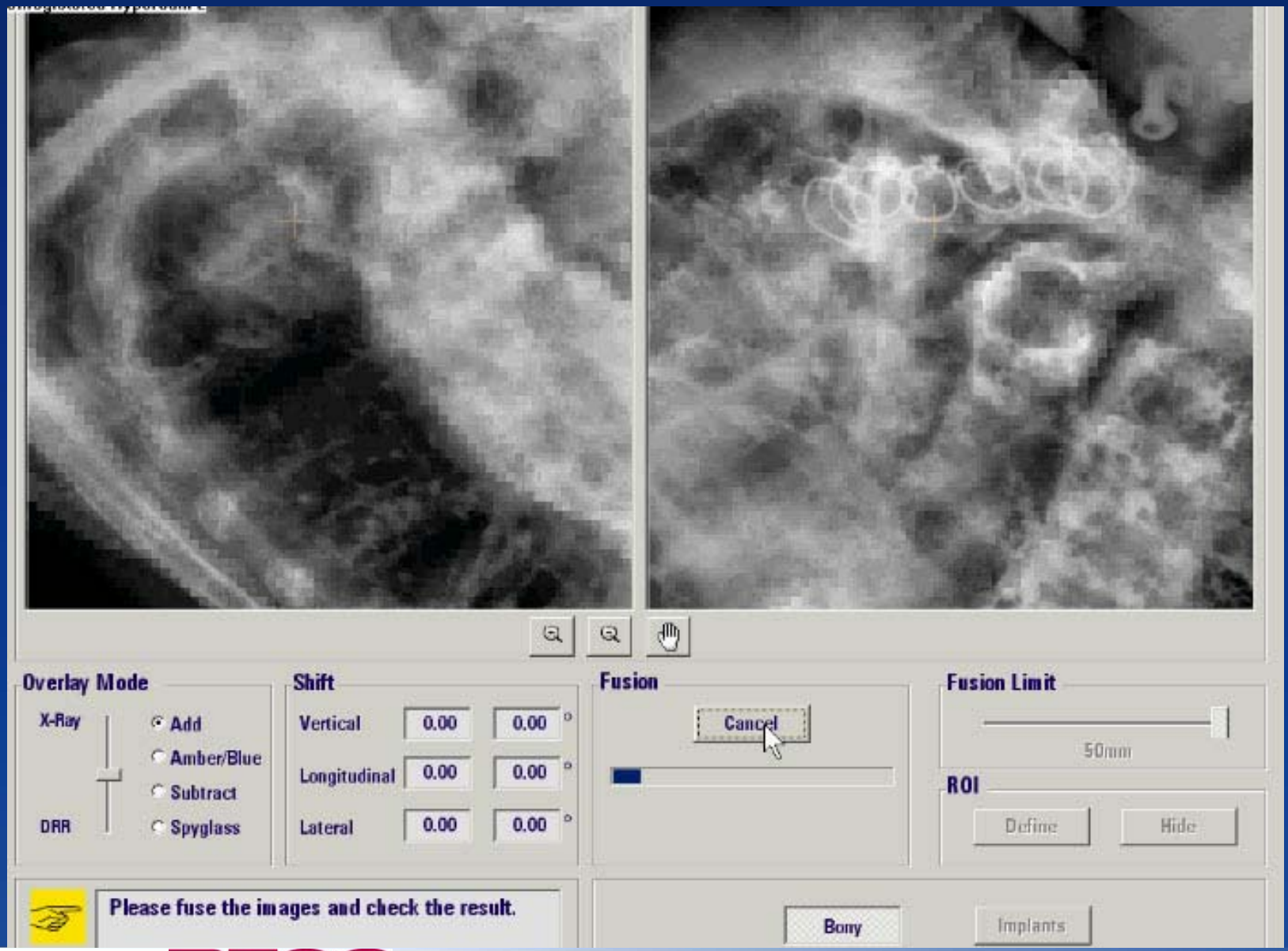

Jefferson


OK
DRR Preview
Contrast
Low
High
Windowing
Enable
Adjust display parameters and press 'Next' to continue.

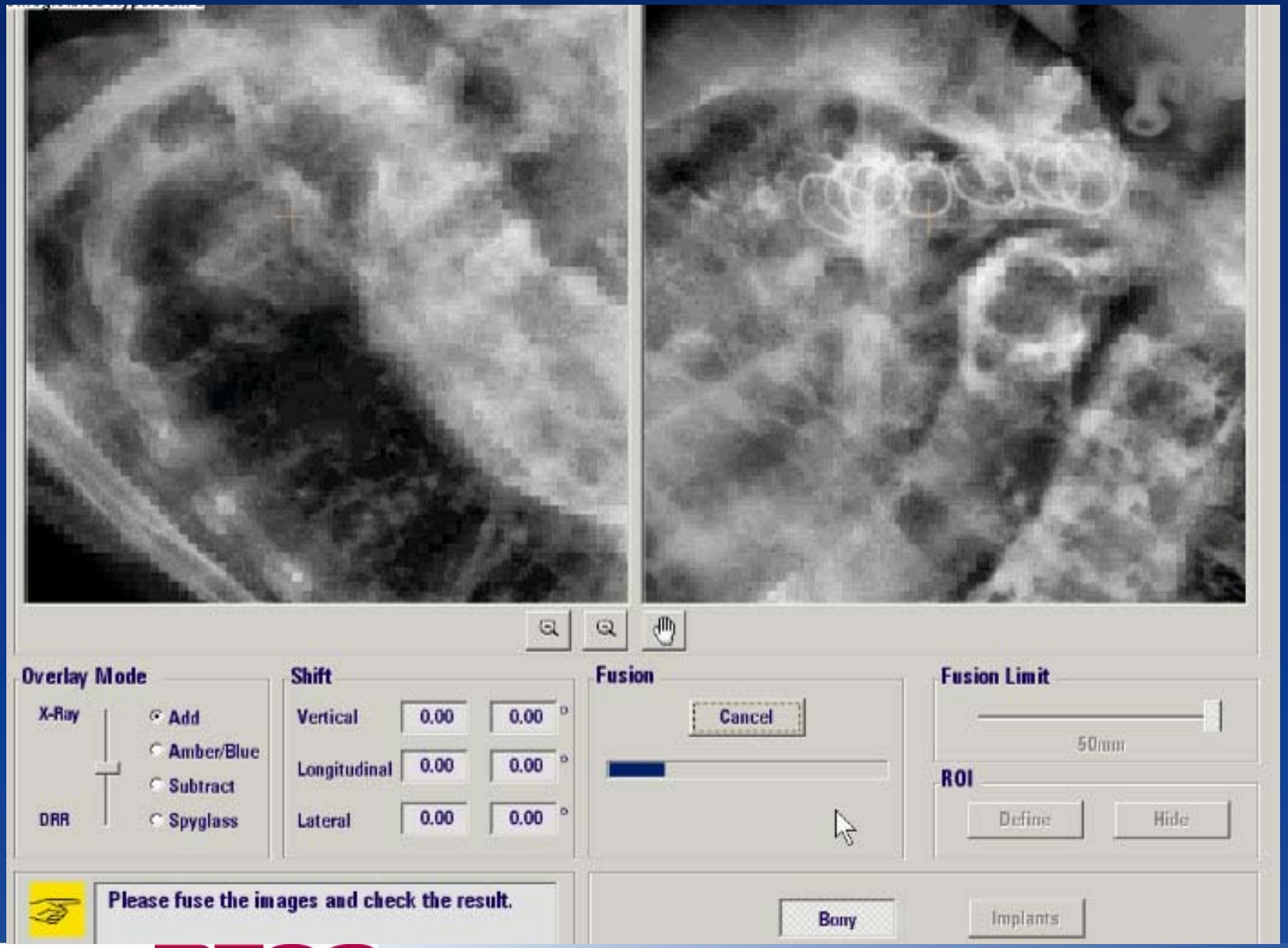

OK
DRR Preview
Contrast
Low
High
Windowing
Enable
Adjust display parameters and press 'Next' to continue.

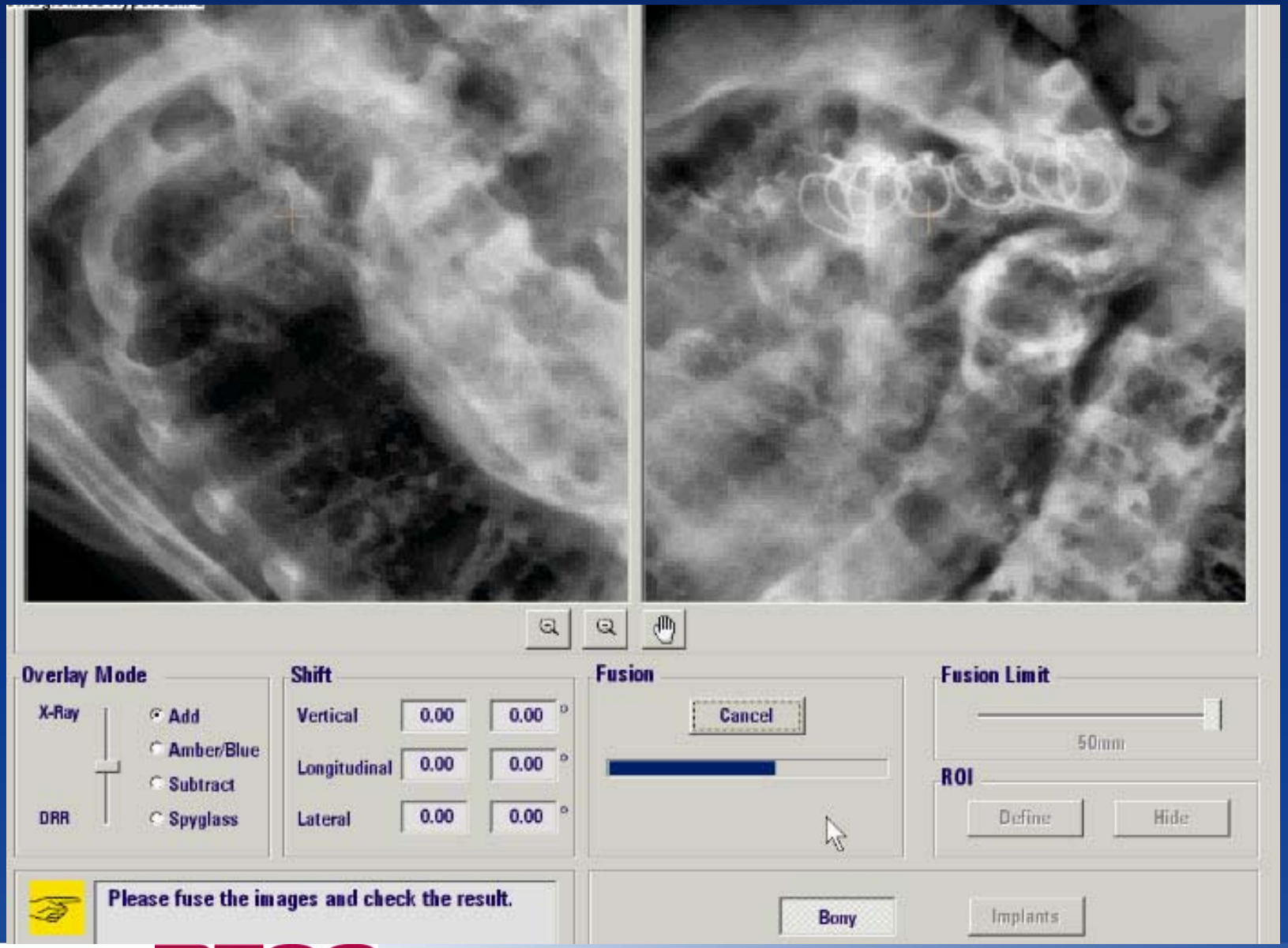

Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
0.00
Fusion
Automatic
Manual
Reset
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants

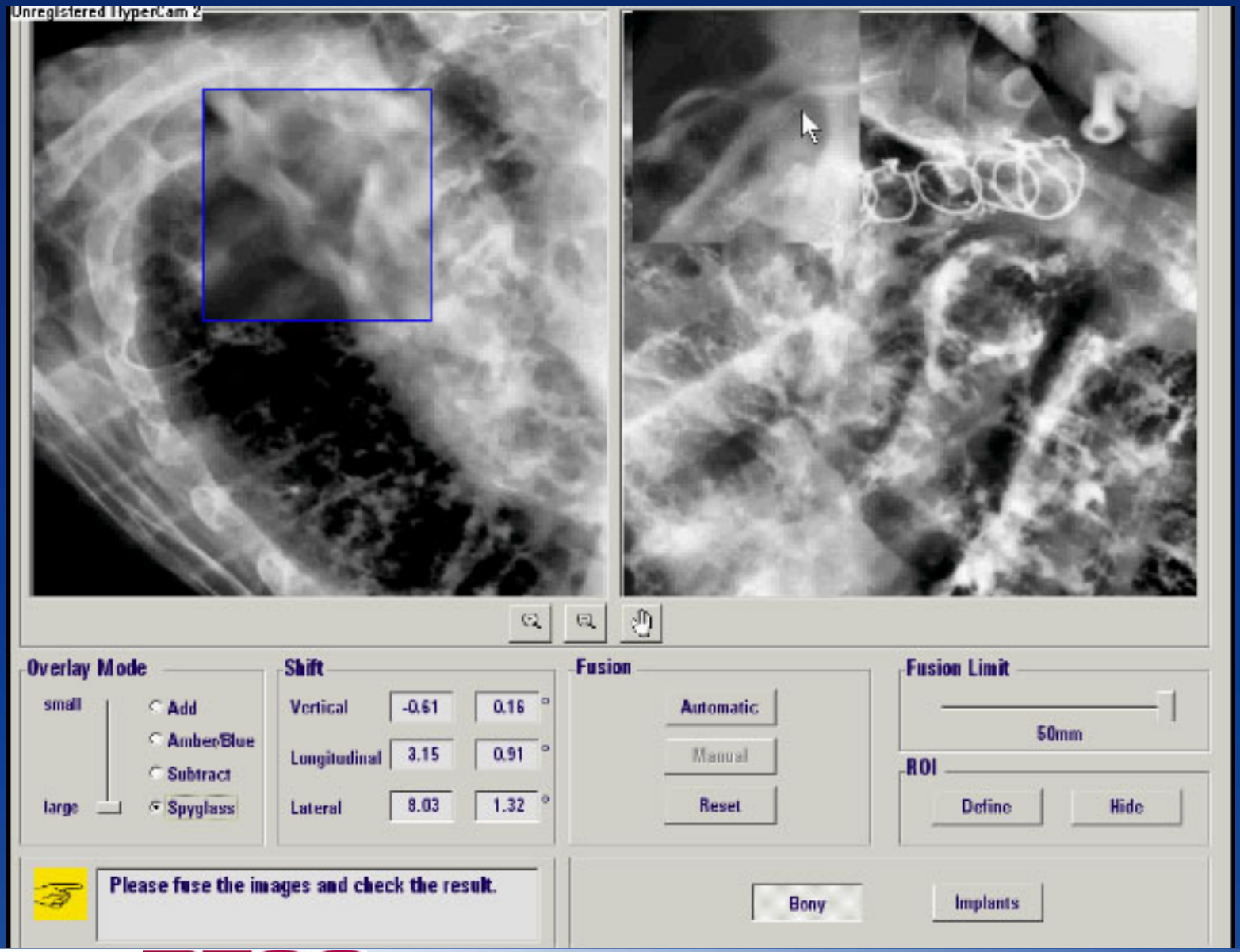

Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
0.00
Fusion
Cancel
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants


Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
0.00
Fusion
Cancel
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants

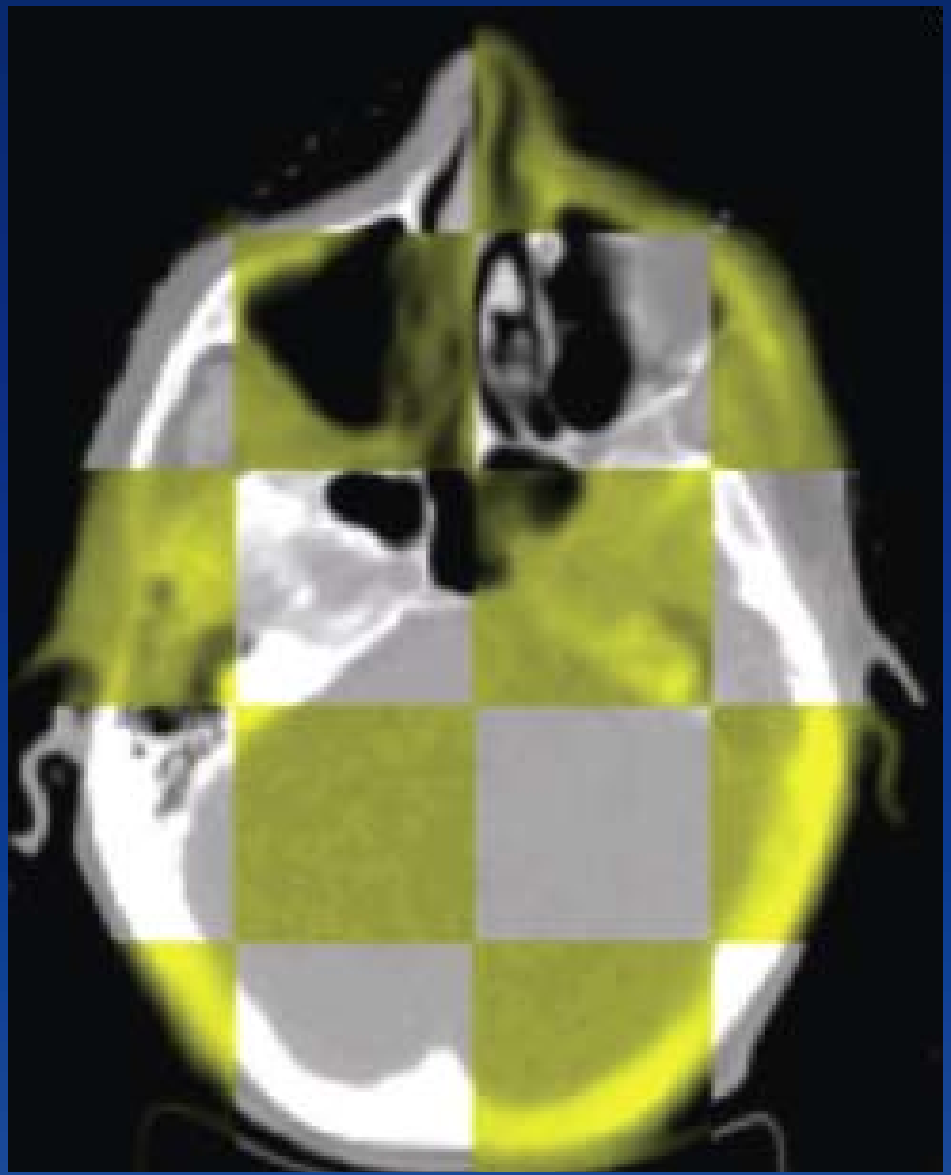

Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
Fusion
Cancel
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants


Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
Fusion
Cancel
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants


Overlay Mode
X-Ray
DRR
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
Longitudinal
Lateral
0.00
Fusion
Cancel
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants


Unregistered HyperCam 2
Overlay Mode
small
large
Add
Amber/Blue
Subtract
Spyglass
Shift
Vertical
-0.61
0.16
Longitudinal
3.15
0.91
Lateral
8.03
1.32
Fusion
Automatic
Manual
Reset
Fusion Limit
50mm
ROI
Define
Hide
Please fuse the images and check the result.
Bony
Implants

- TomoTherapy "checkerboard" fusion review



Error Detection based on: Automatic 6D Fusion

Translation Error:


Vert. -0.61 mm


Long. +3.15 mm


Lat. +8.03 mm

Rotation around isocenter:


Tab. +0.16 °


Long. +0.91 °


Lat. +1.32 °

# Concern About Peripheral Dose

There is plenty of evidence to show the advantages of using CT for planning; there is equally evidence to demonstrate that portal images are essential to sustain accurate coverage of the target and avoid critical structures. So these extra-target doses are an essential part of the whole process of accurate delivery of the prescribed dose. However, this is not to say that any amount of extra-target dose can be given.

**E. G. A. Aird - British Journal of Radiology (2004) 77, 983-985**

# Concern About Peripheral Dose

The 17-year-old female having "involved field irradiation" for Hodgkin's lymphoma is not in the same category as the 70-year-old male treated for prostate cancer.

**E. G. A. Aird - British Journal of Radiology (2004) 77, 983-985**

# Useful Publications

- Martin J. Murphy, et al  The management of imaging dose during image-guided radiotherapy - Report of the AAPM Task Group 75  *Medical Physics* 34, 4041-4063, 2007
- Mohammad K. Islam, et al  Patient dose from kilovoltage cone beam computed tomography imaging in radiation therapy *Medical Physics* 33, 1573-1582, 2006

# Other Contributions to Peripheral Dose

- **Leakage Radiation**
  - 0.2% or less
  - IMRT decreases efficiency so that leakage goes up by x3
  - Thus, 60 Gy target dose gives about 360 mGy leakage dose
- **Scatter Dose and Dose from Non-coplanar Fields**
  - Near target volume receiving 60 Gy, scatter can be 300-3000 mGy (10 to 1 cm away)
- **Single planning CT study**
  - 30-50 mGy
- **Standard portal imaging**
  - Film 50-100 mGy per image EPID 10-50 mGy per image

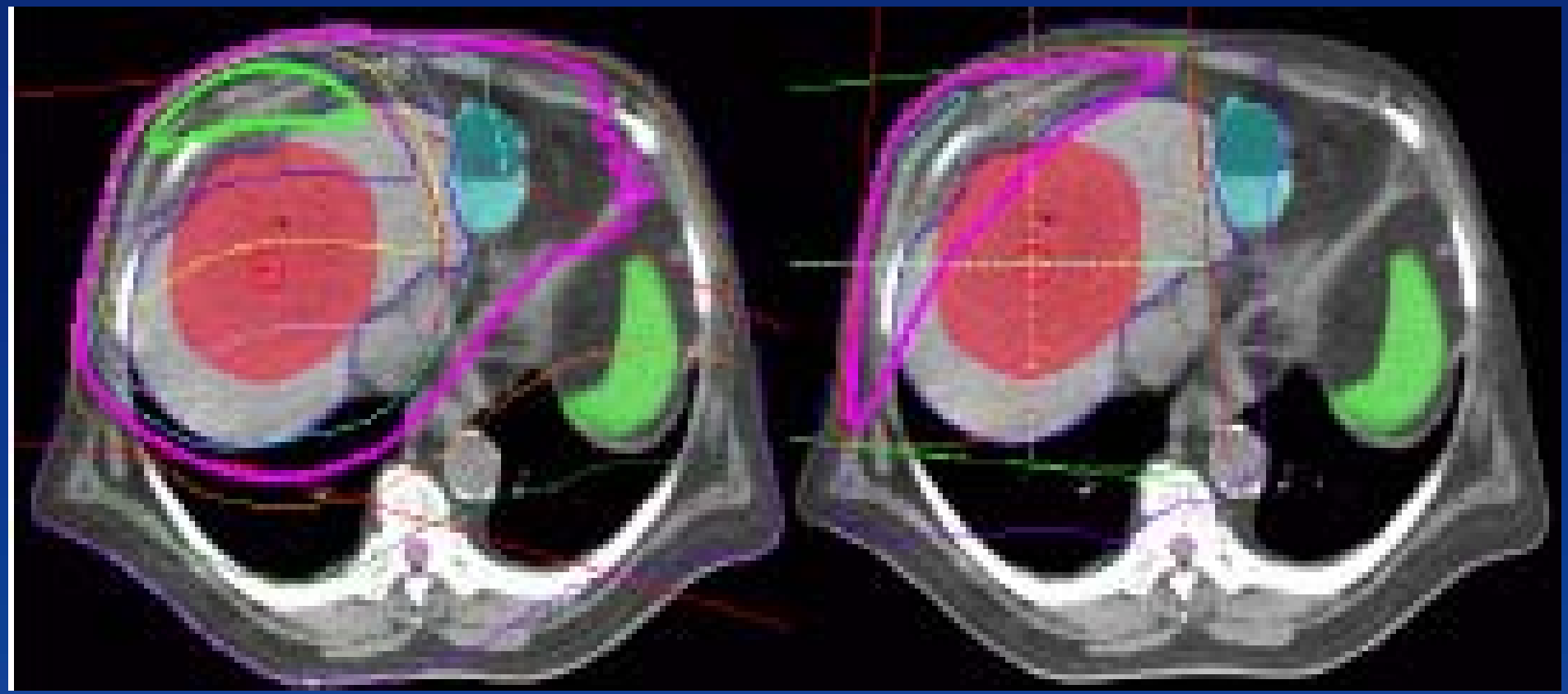
# Peripheral Dose from IGRT
# CT Dose Index (CTDI)

- **Elekta Cone-Beam CT**
  - Mean dose at center — Head/Torso — 2/34 mGy
- **TomoTherapy Helical MV CT**
  - Depends on pitch, slice thickness — Head/Torso — 25/18 mGy
- **Varian Cone-Beam CT**
  - Depends on bow-tie filter, degrees of rotation, grid? — Head/Torso — 83/42 mGy
- **Siemens MV Cone-Beam CT**
  - MV cone-beam — 50-150 mGy

# Peripheral Dose from IGRT
# CT Dose Index (CTDI)

- **Elekta Stereoscopic kV Imaging**
  - Dose about a factor of ten less than cone-beam with same unit

# Peripheral Dose from IGRT



Lee-Cheng Peng, et al J Appl Clin Med Phys Vol 8 No 1(2007)

9 MU cone-beam

4 MU orthogs

# Probability of Inducing a Fatal Cancer

- ICRP coefficient for estimating the probability of inducing a fatal cancer from a single radiographic exposure is $5x10^{-5}$ per mSv of effective dose

# Probability of Inducing a Fatal Cancer

- Consider a prostate treatment that uses CT for planning followed by 30 daily portal image pairs at 2 MU each.
- For the CT part of the procedure, the Effective Dose has been estimated at 8.2 mSv
- For the portal imaging part of the procedure, the Effective Dose is estimated as 1.3 mSv
- The total Effective Dose is 8.2 + 30x1.3 = 47.2 mSv
- Thus, using the equation from the previous slide, there is an estimated probability of 0.2% for radiation-induced cancer in the patient's lifetime.

# Probability of Inducing a Fatal Cancer

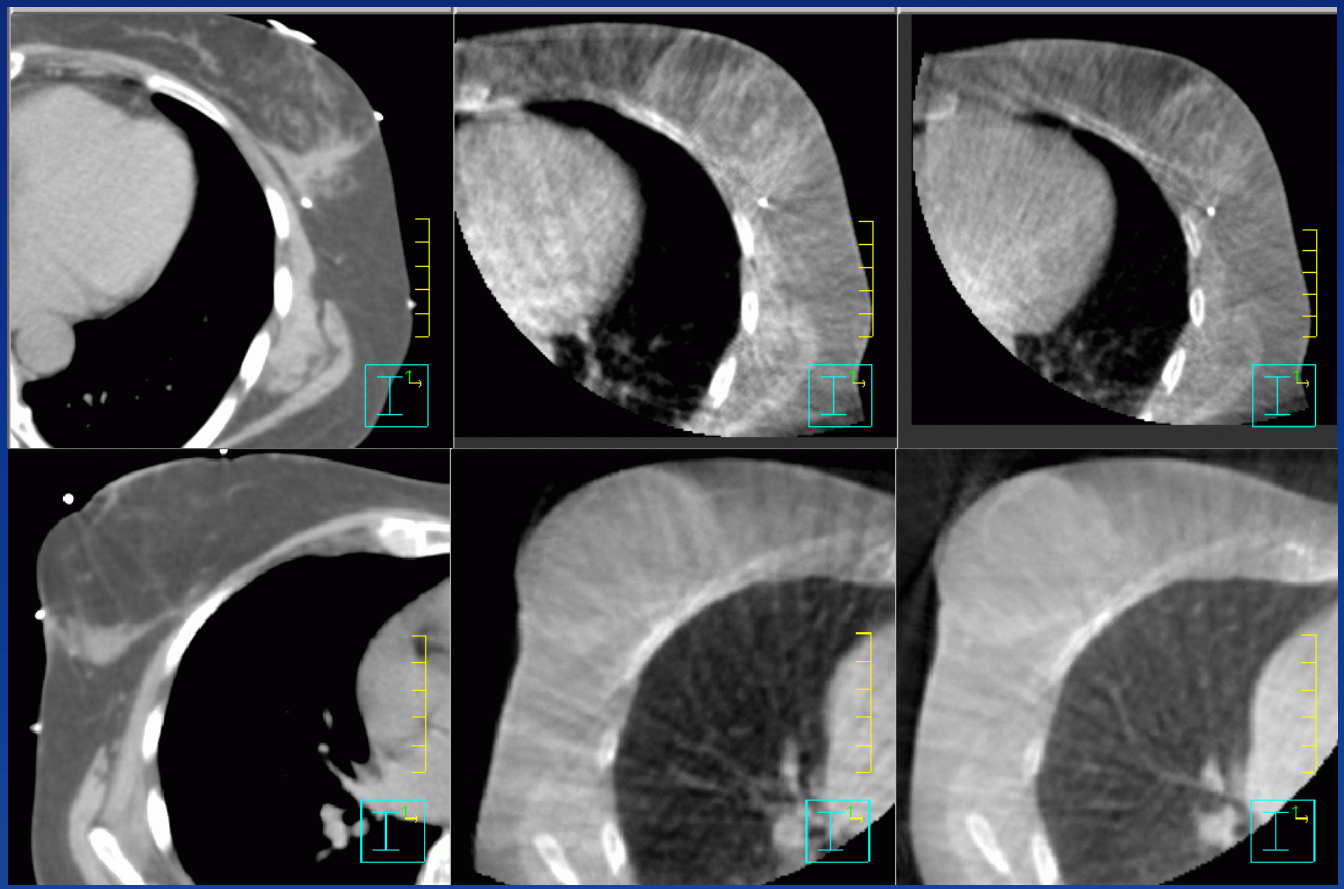
- Consider a thirty-year-old female being treated for cervical cancer. If this patient undergoes 30 complete daily in-room CTs for targeting and compensation of organ deformation, she receives an estimated Effective Dose of 246 mSv.
- This situation gives a 1.2% probability of a radiation-induced cancer.

# Dose Reduction Strategies for Cone-Beam CT

- Minimize the longitudinal field of view
- Reduce number of projections and/or the mAs settings per projection
- Use a lower kV
- Scan with partial rotation

Islam, et al

# Breast Cone-Beam – Courtesy of Di Yan PhD Beaumont Hospital



Helical CT CB CT

Start/stop Ang: 180/300
# projections: 435
Proj/total mAs: 0.25/109
0.5/217
XVI Insert: S20
Max dose (cGy): 0.7/1.3

Start/stop Ang: 80/-180
# projections: 470
Proj/total mAs: 0.8/376
XVI Insert: S20
Max dose (cGy): 2.3

# Dose Reduction Strategies for IGRT

- Configure the image acquisition systems to eliminate dose outside the required fields of view
- Plan the imaging technique to be consistent with the image quality and information needed for the treatment decision being made

Murphy, et al

# Dose Reduction Strategies for IGRT – The NKI Technique

- Use the first week of treatment to define systematic errors with daily imaging
- Correct and image weekly thereafter