



Image Guided Radiation Therapy – Edward Experience

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Outline

- PET/CT Simulation
- Manage Respiratory Motion – 4DCT Simulation
- On Board Imaging



Challenges in Radiation Therapy

- Identifying the tumor
- Defining the tumor and target
- Hitting the target
- Knowing the tumor response to radiation

Imaging and image registration is the key for addressing these challenges

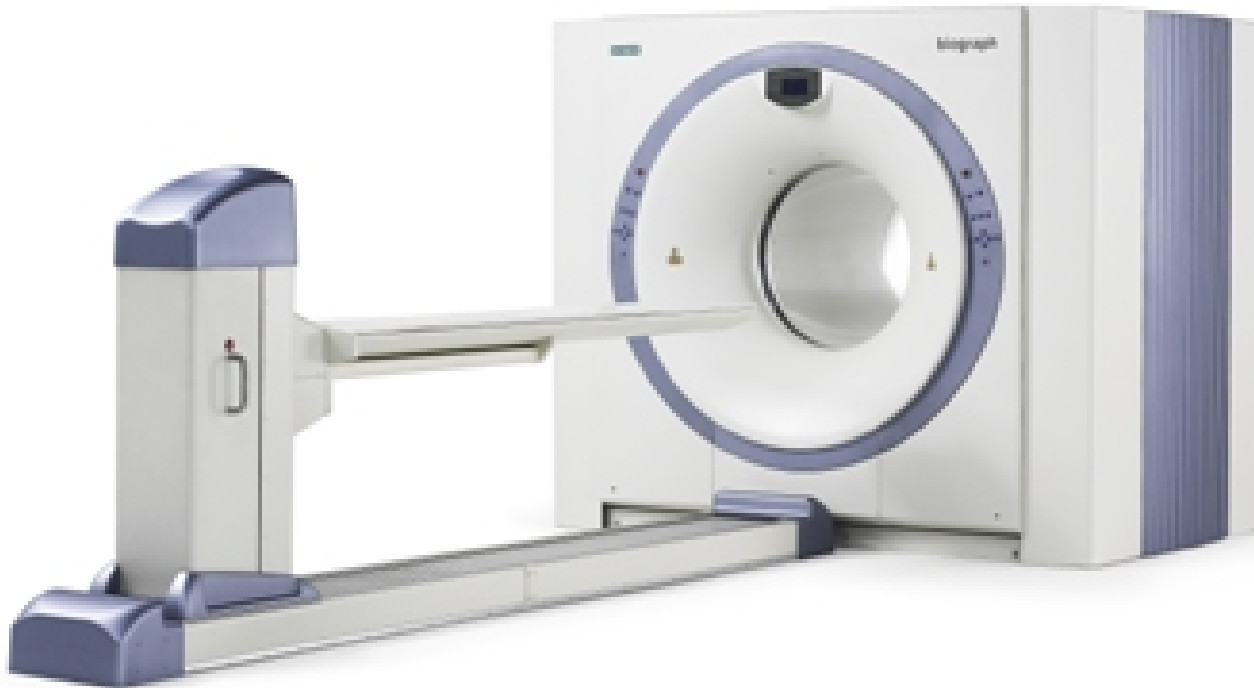


Imaging Techniques are Rarely Used “Solo”

- CT
- MR
- PET
- Ultrasound
- PET/CT Simulation
- 4DCT Simulation
- On Board Imaging



PET for Radiation Therapy Planning

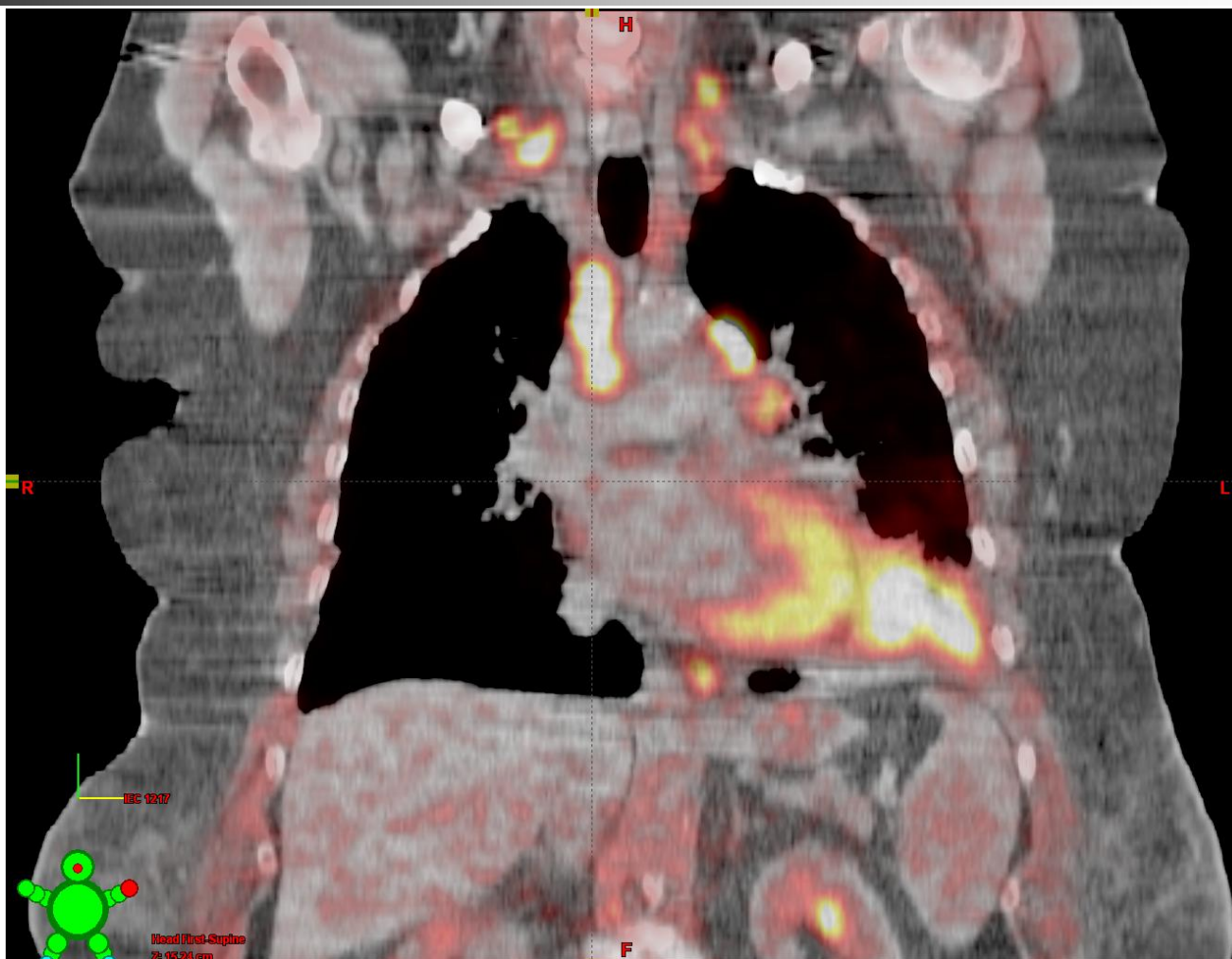




Why PET/CT Simulation?

- Distribution of activity is imaged
 - Physiology, function, biology
- Complementary to (~ anatomic) CT and MR
- Increased sensitivity compared to CT alone
- PET and CT in the same treatment position
- Accurate PET/CT fusion

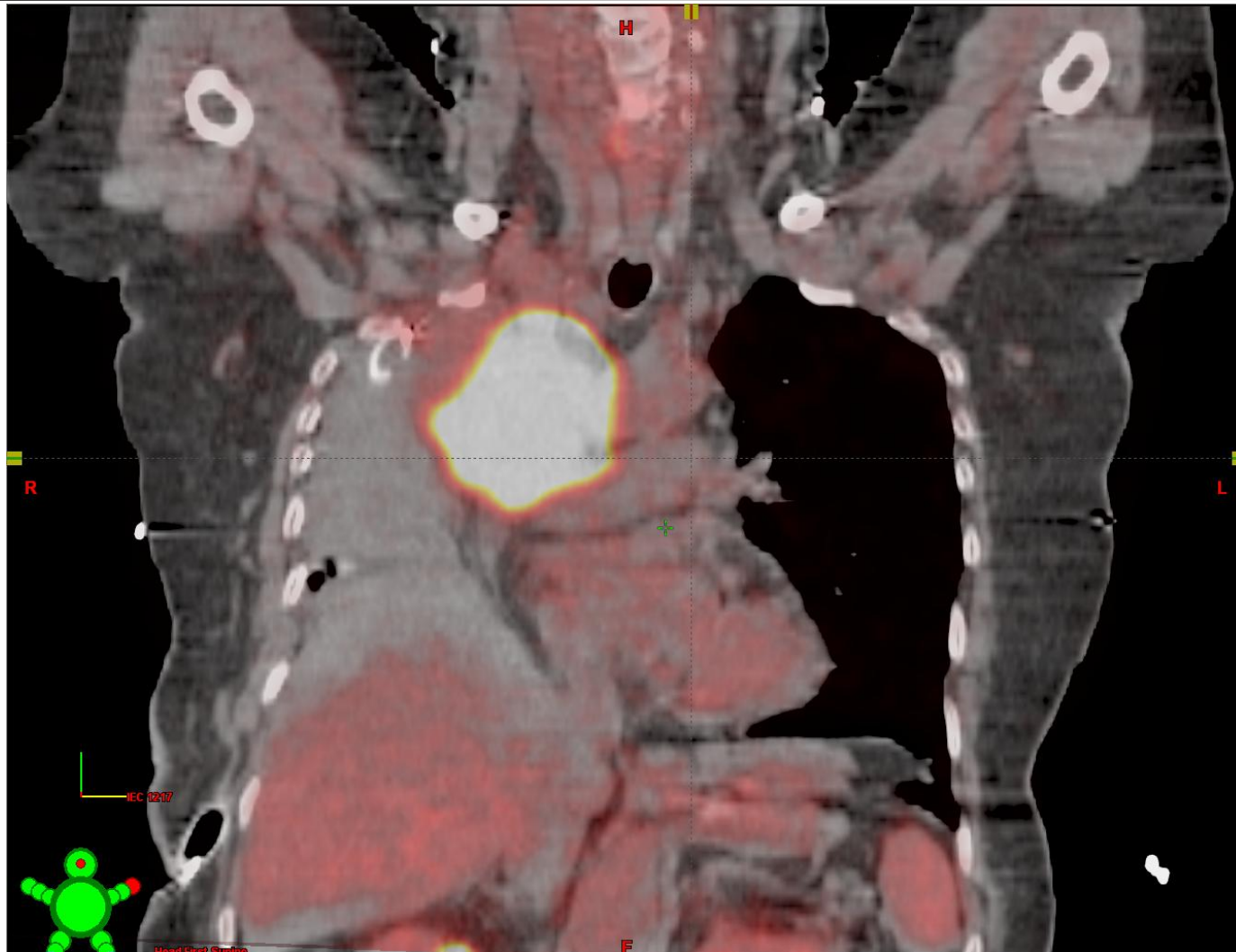
PET/CT Simulation



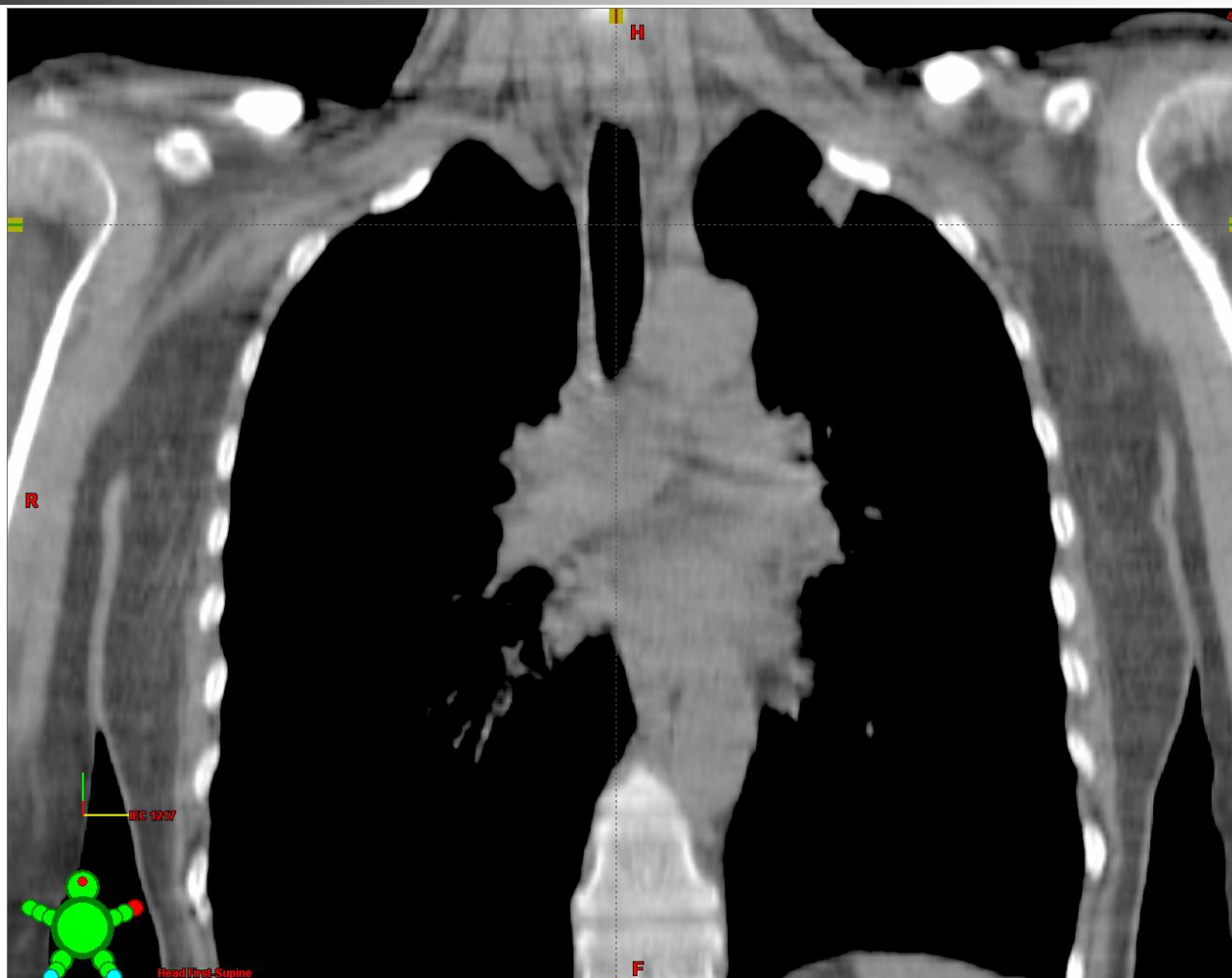
PET can Decrease Target Volume



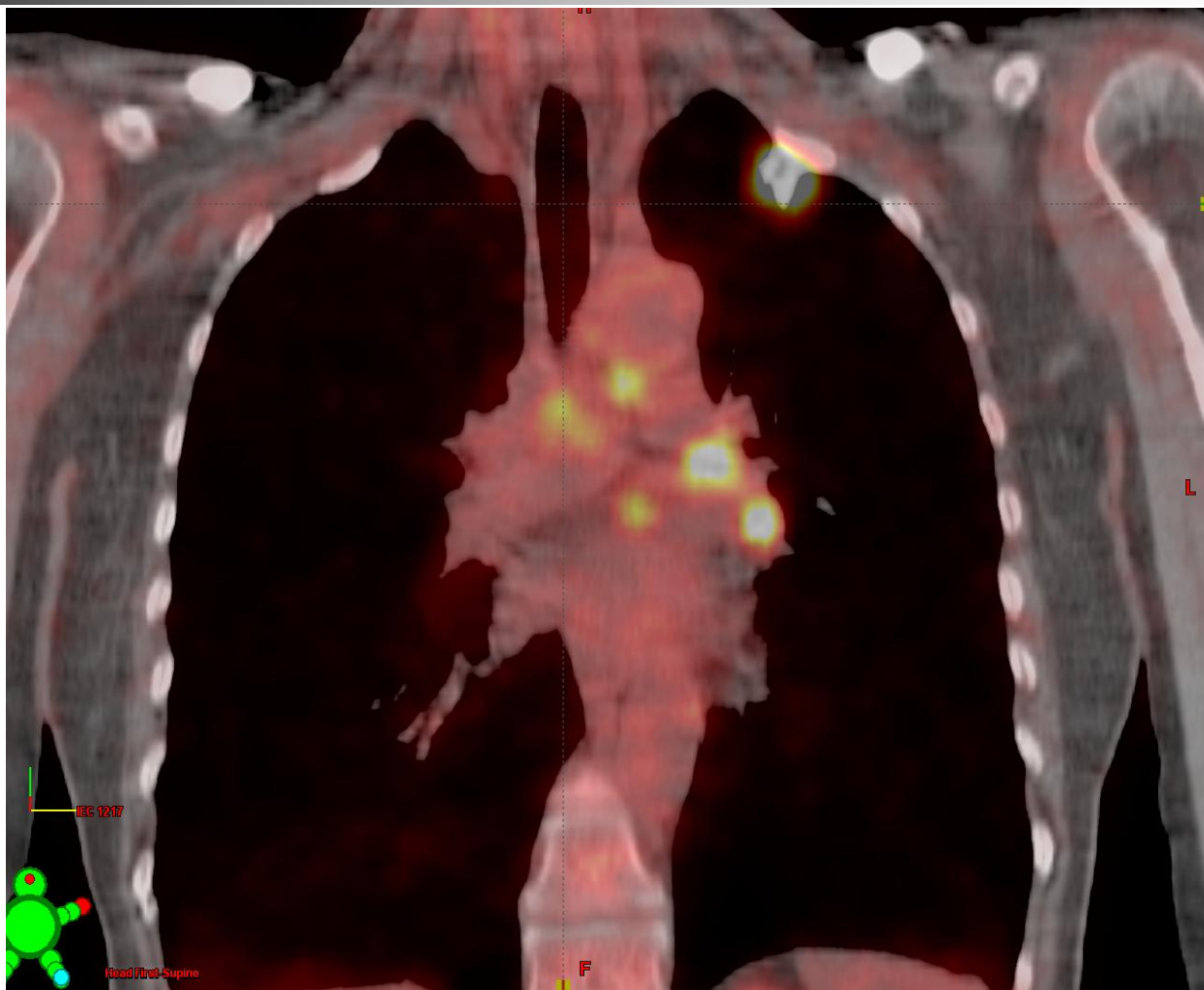
PET can Decrease Target Volume



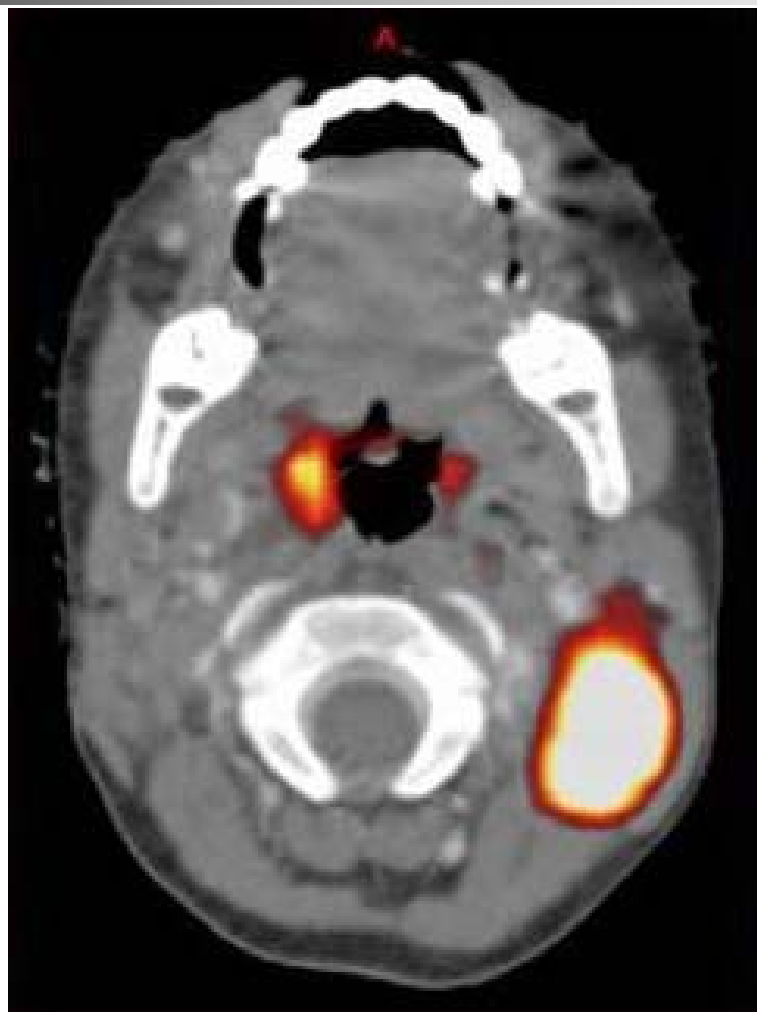
PET can Increase Target Volume

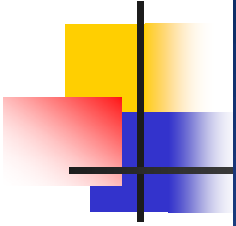


PET can Increase Target Volume



PET can Increase Target Volume





Are they Moving?



More Challenges in Radiation Therapy

- Identifying the tumor
- Defining the **moving** tumor and target
- Hitting the **moving** target
- Knowing the tumor response to radiation



Types of Motion

- Intra-fraction
 - Within each fraction (example: lung)
- Inter-fraction
 - Between fractions (example: prostate)
- Combined with deformation
 - Example: pancreas

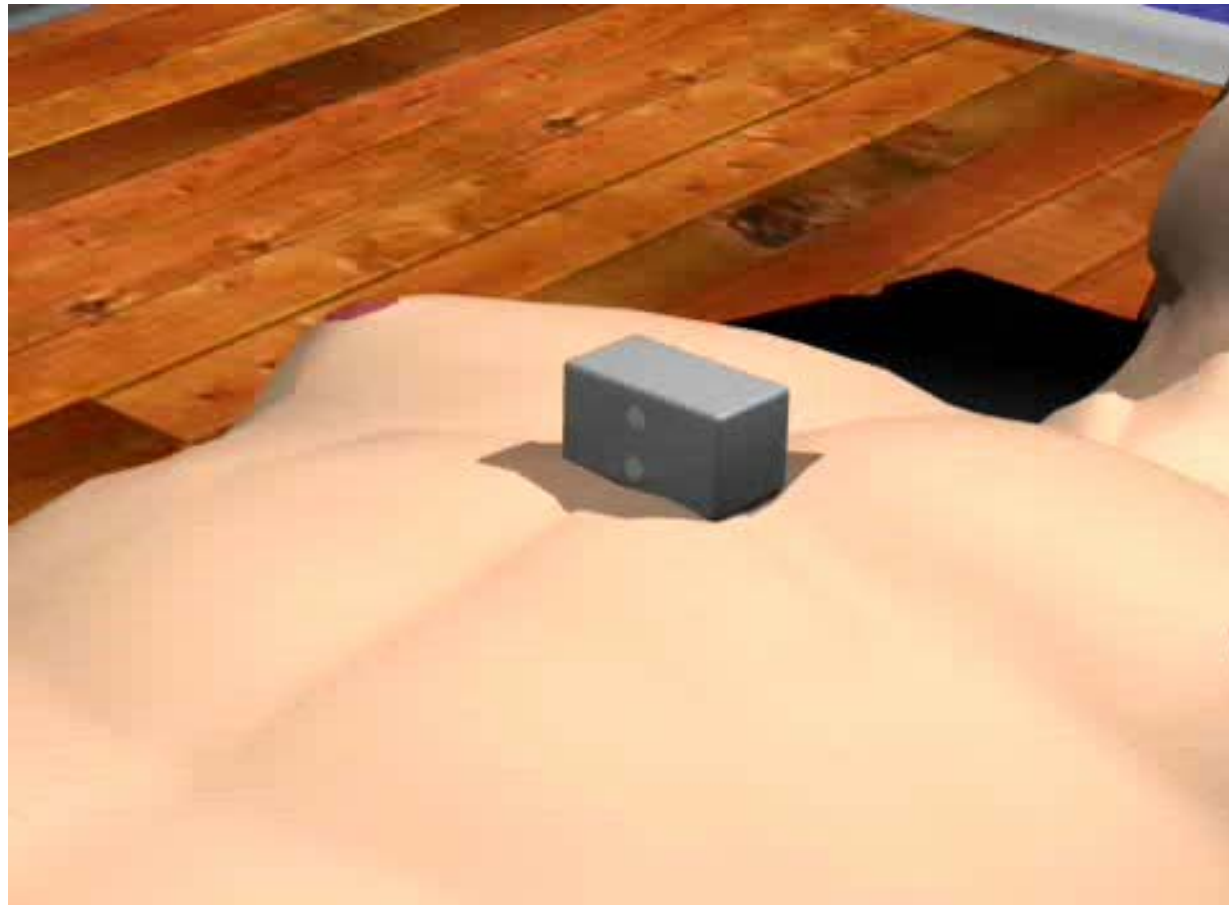
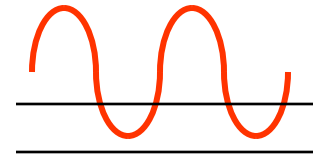


How to Monitor Breathing?

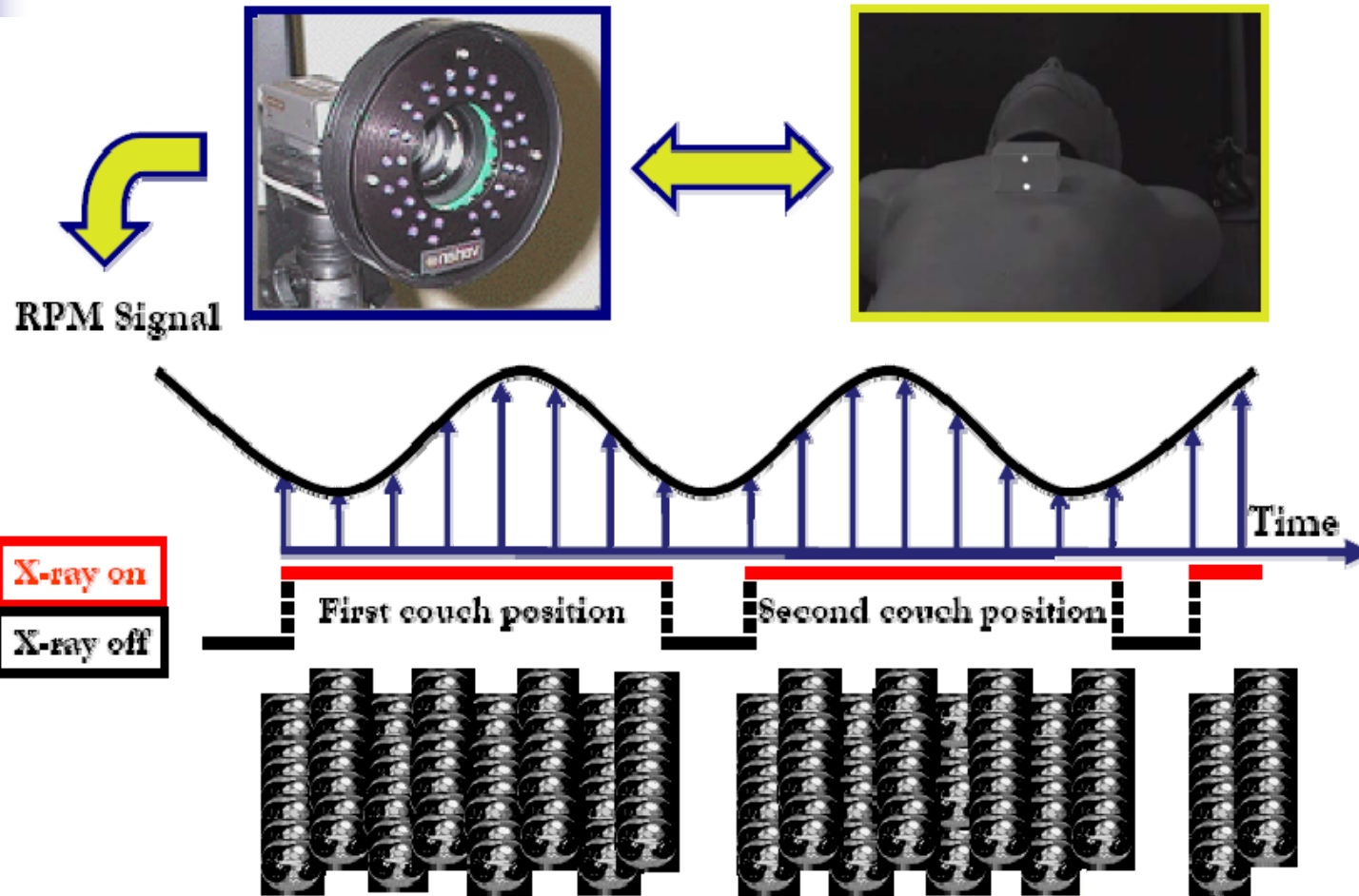
- Chest / abdomen height
 - Varian RPM System
- Belt based
 - Anzi Medical System (pressure based belt)
 - Philips (pneumatic belt)
- Metric spirometry



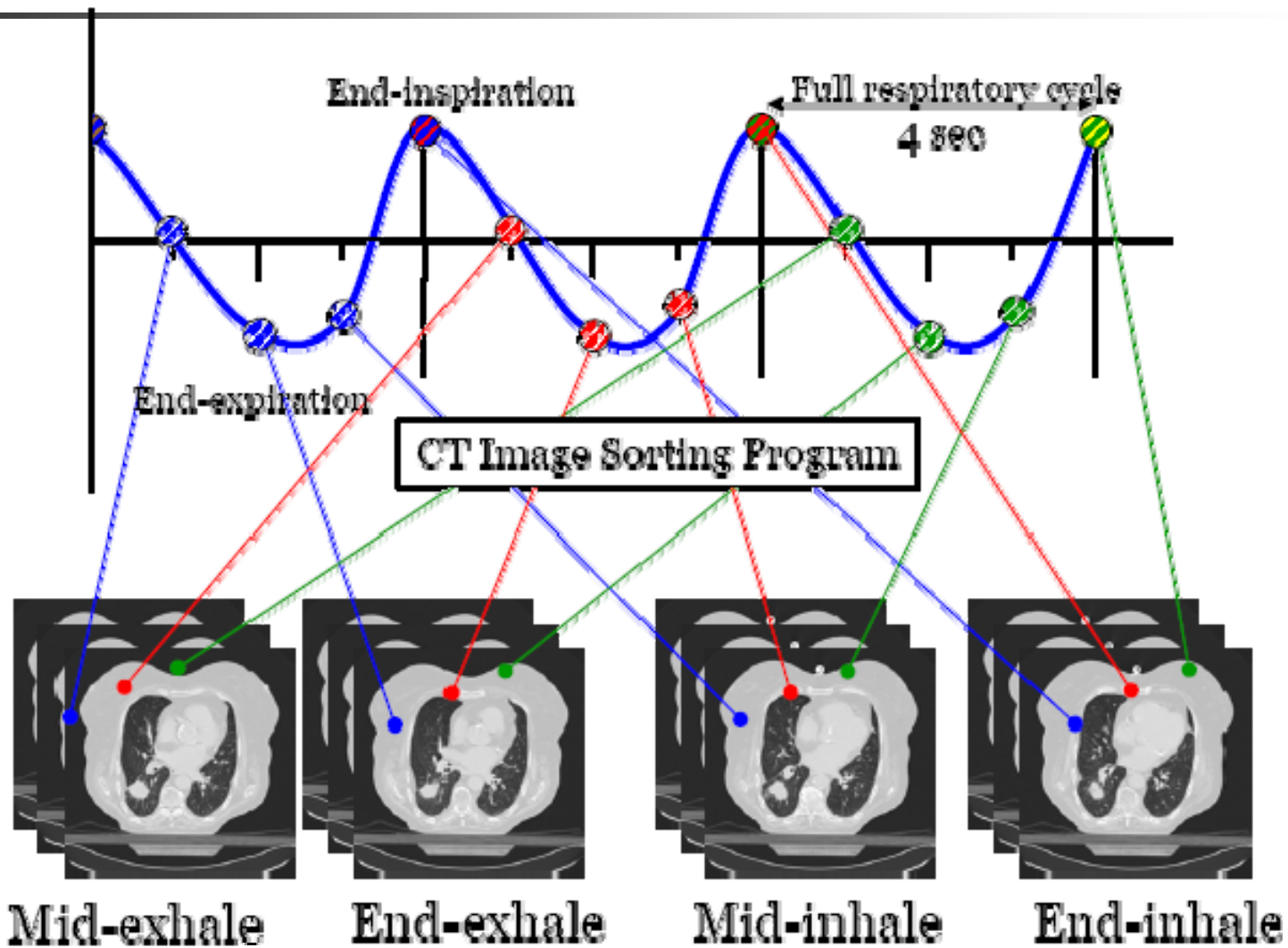
Varian RPM



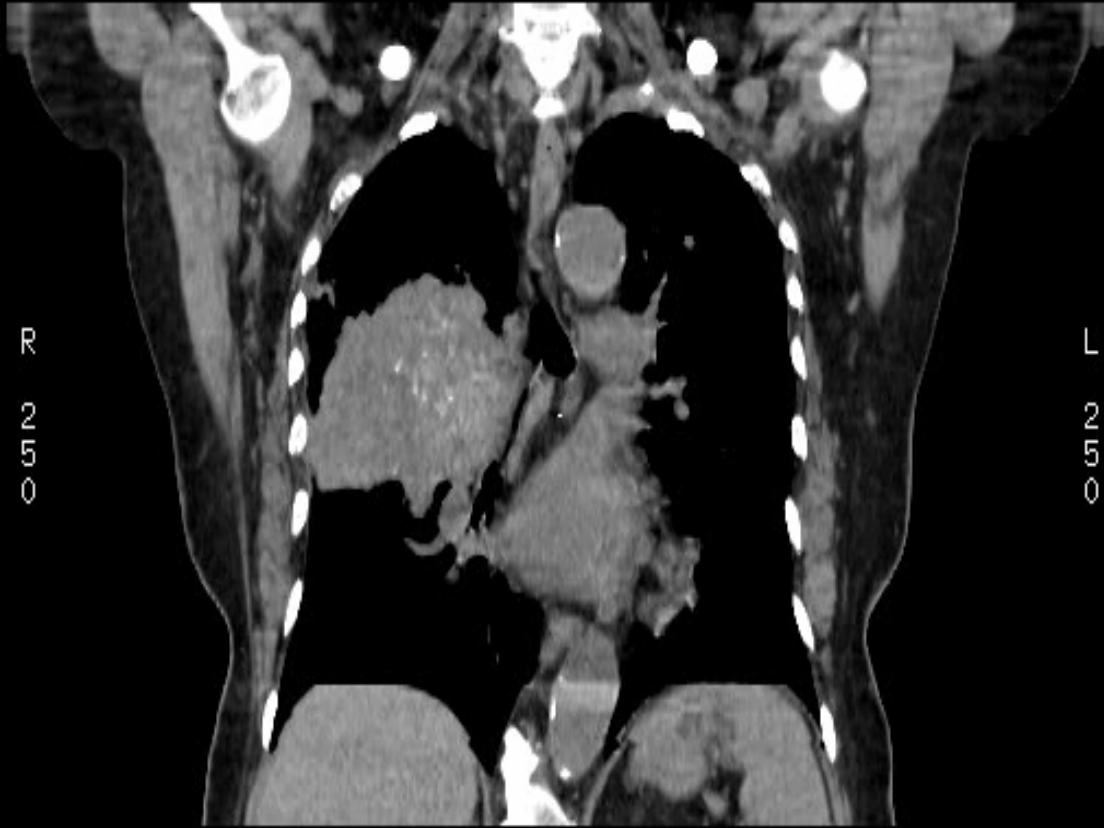
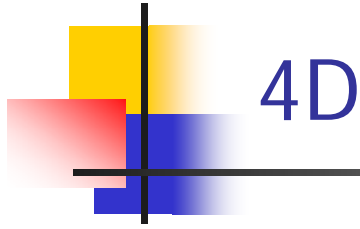
4D CT Imaging



4DCT Image Sorting



1.0 / 2.5mm / 2.5sp
DFDV 50.0cm
Mon Jan 22 10:13:42 2007



R
250

L
250

1.0 /

Test

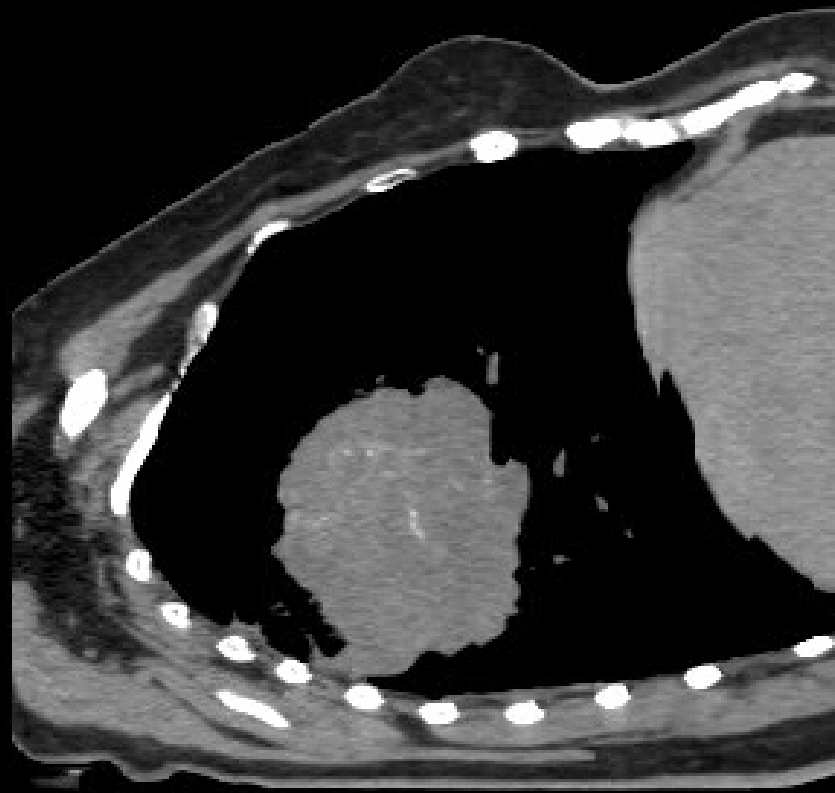
W = 350 L = 40

I 148

WW: 255WL: 128

087 500
R: 63.0
2.5mm /2.5sp
DFDW 50.0cm

0000001
Mon Jan 22 10:13:42 2007



S
3
5
1

I
1
4
8

1.0 /

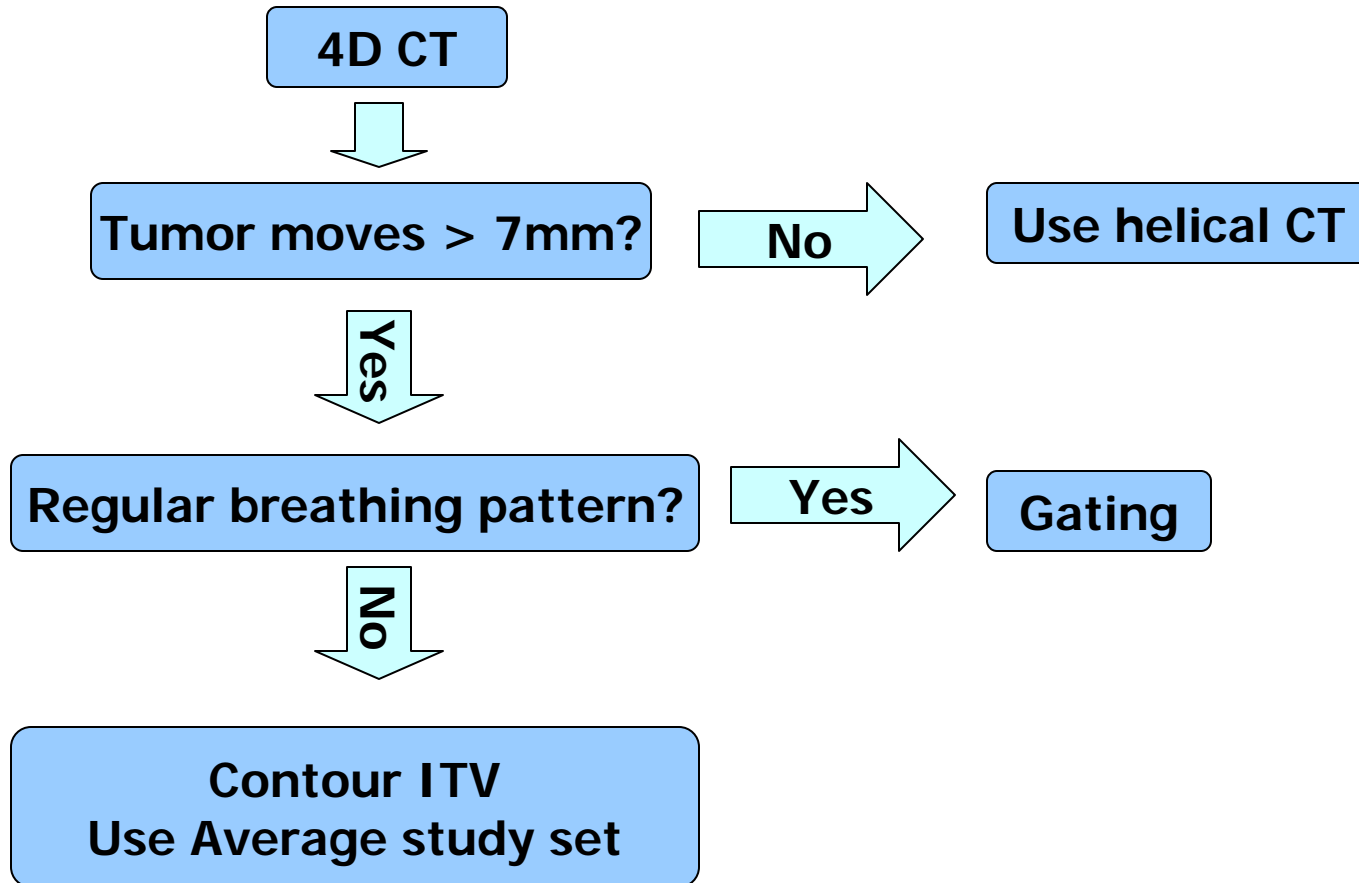
Test_sag

W = 400 L = 40

P 250

WW: 255WL: 128

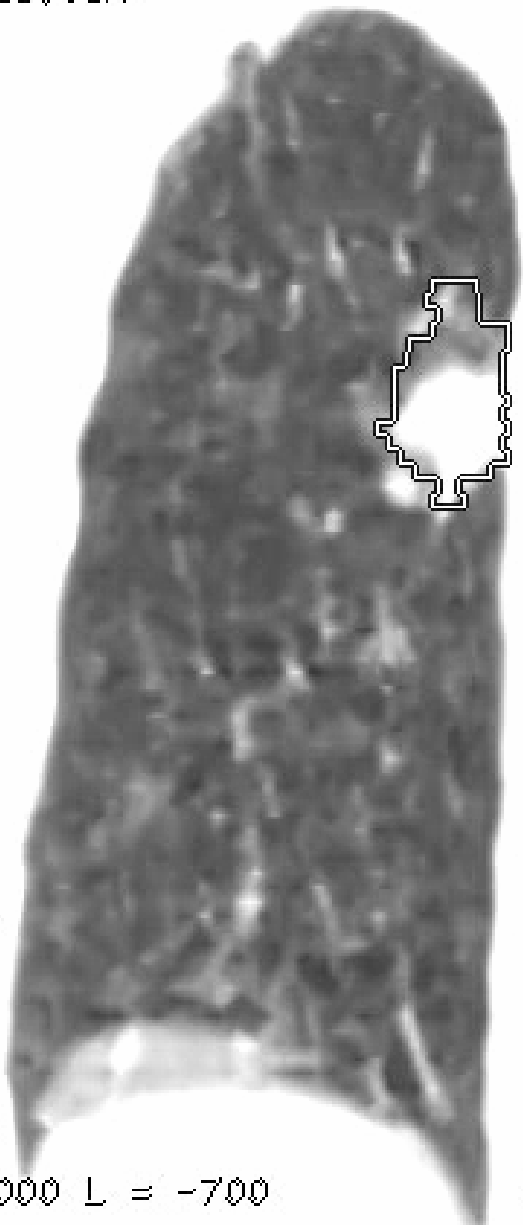
Manage Respiratory Motion



rs 10.1
2,5mm / 2,5sp
DFDW 25,0cm

100 MAR 1 10%09%02 2001

R
001-1



L
001-1



1.0 /

test2

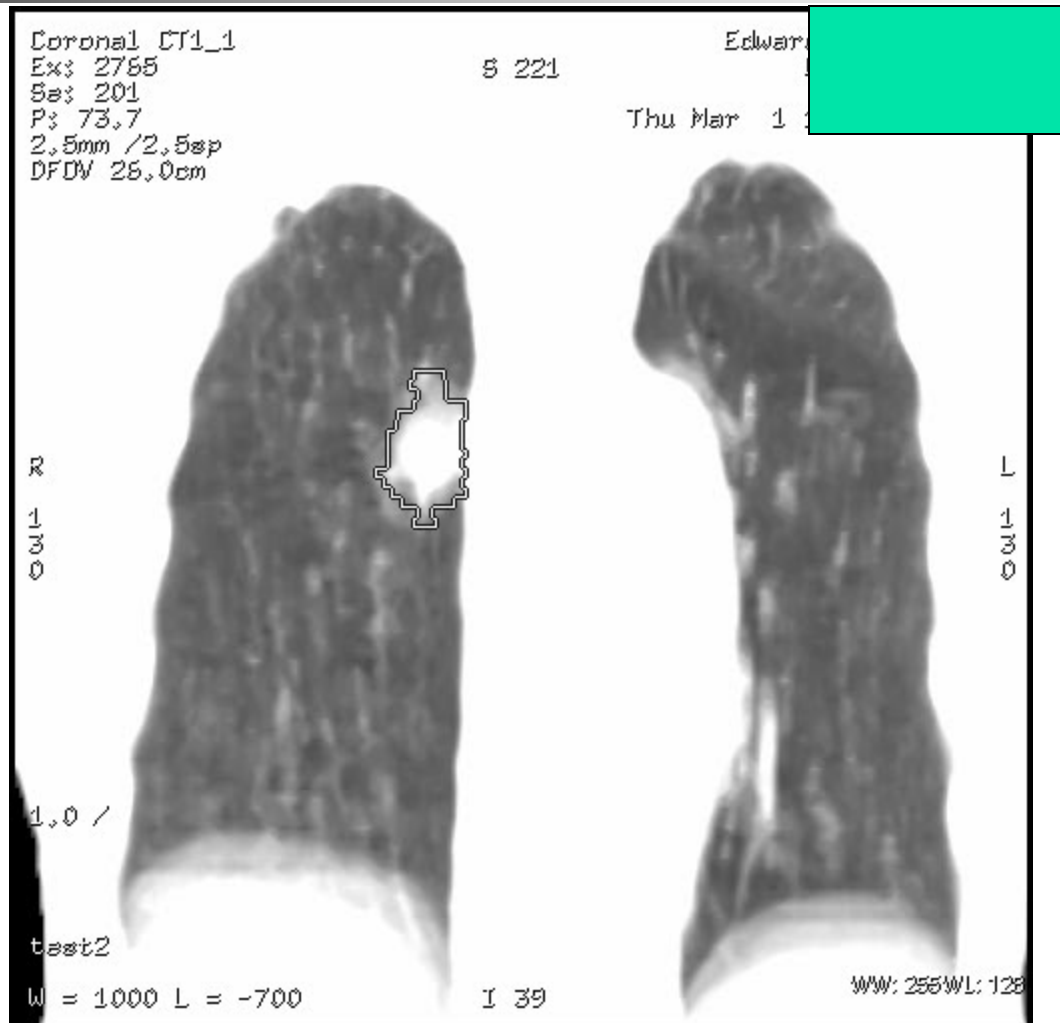
W = 1000 L = -700

I 39

WW: 255WL: 128



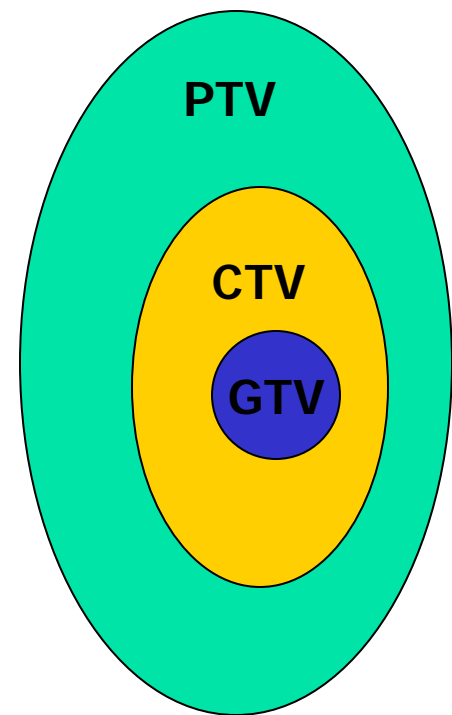
ITV on Ave Study Set for Planning





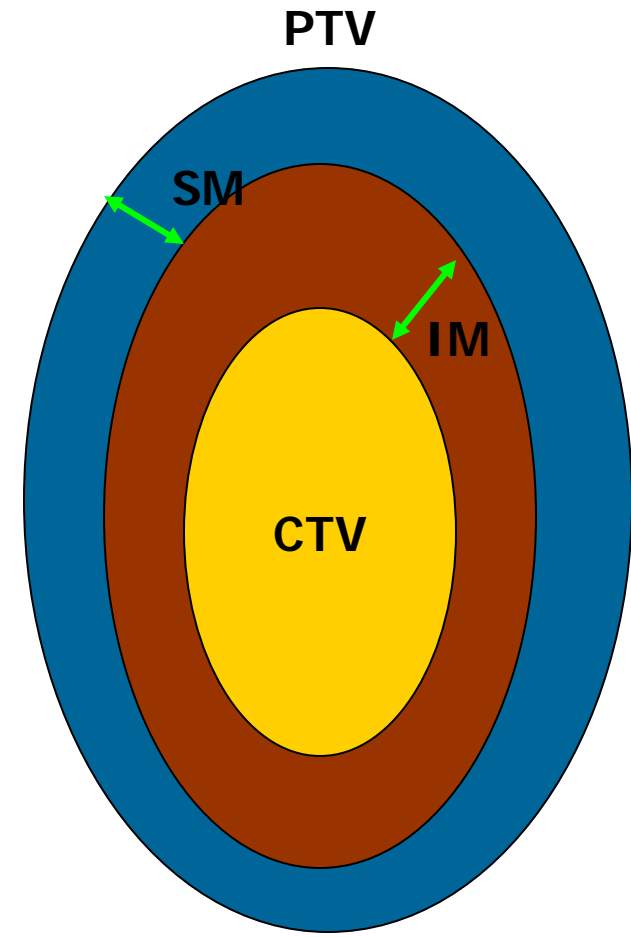
ICRU 62 Target Volume Delineation

- GTV – Gross Tumor Volume
- CTV – Clinical Target Volume
- PTV – Planning Target Volume



ICRU 62 Target Volume Delineation

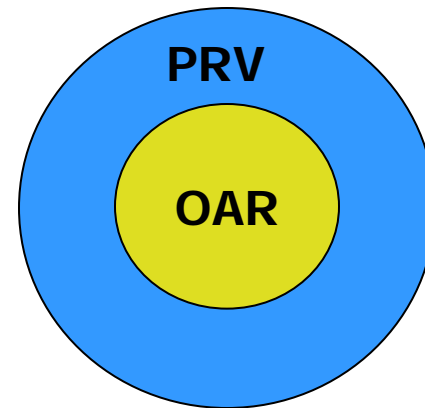
- $PTV = CTV + IM + SM$
 - IM - Internal Margin, due to physiologic variations
 - SM - Setup Margin, due to technical factors





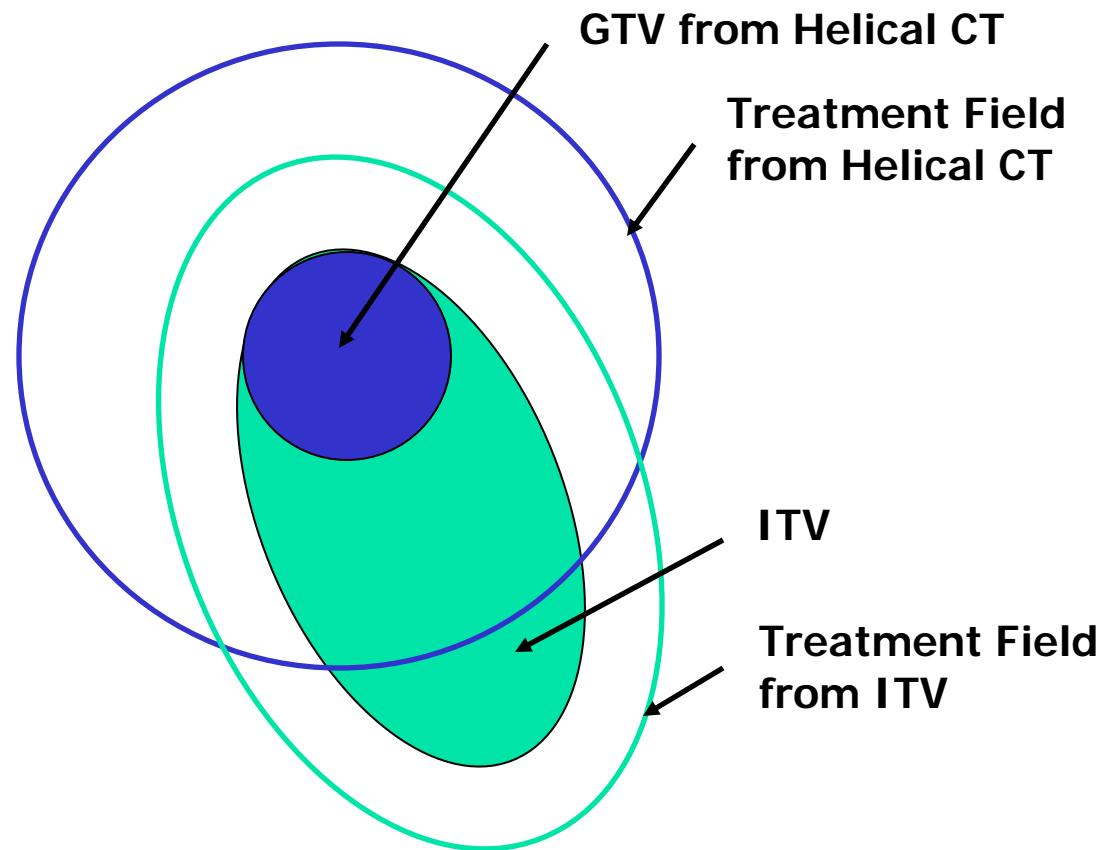
ICRU 62 Definition

- OAR – Organ at Risk
- PRV – Planning Organ at Risk Volume
 - Margin added to OARs

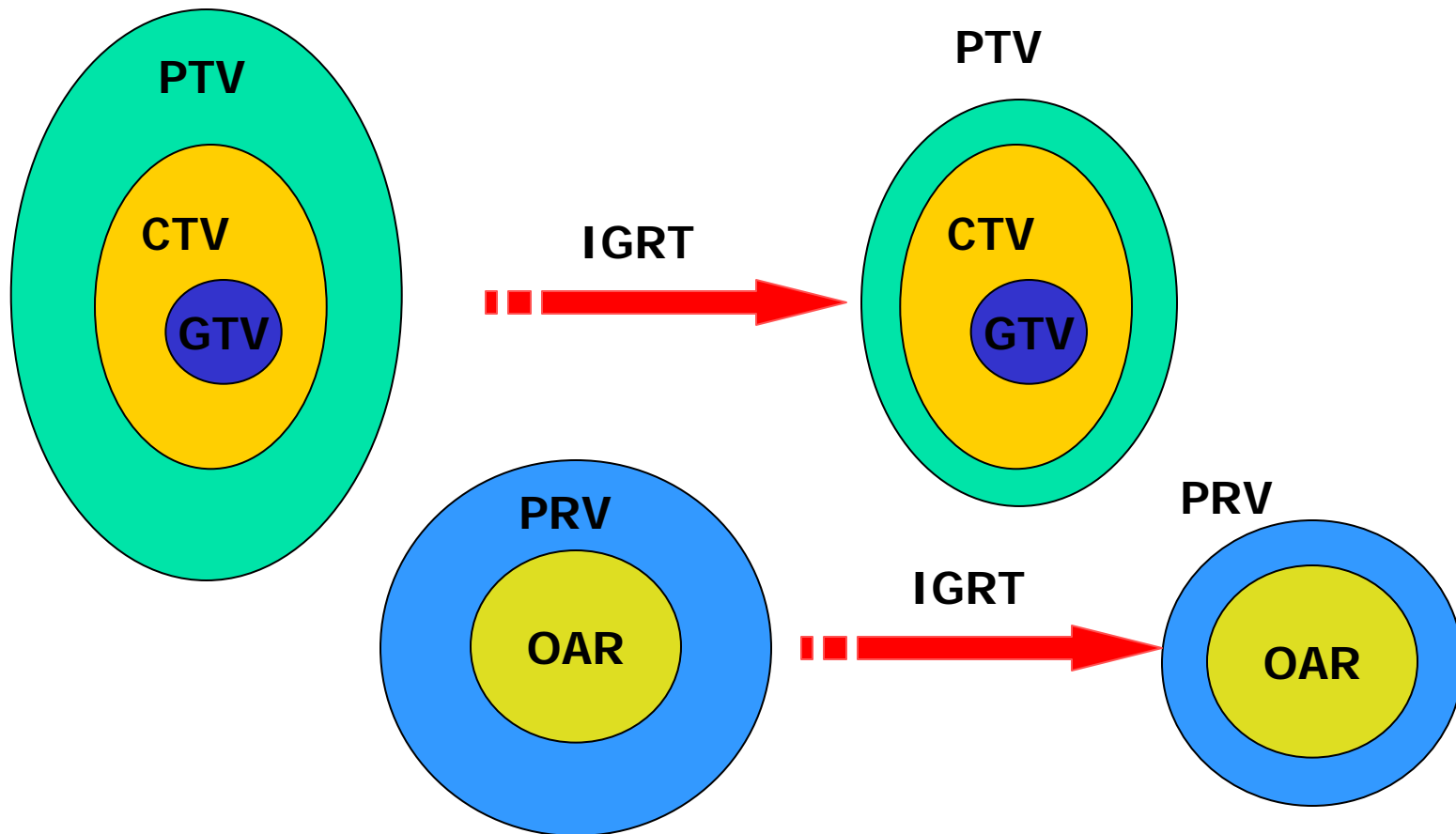




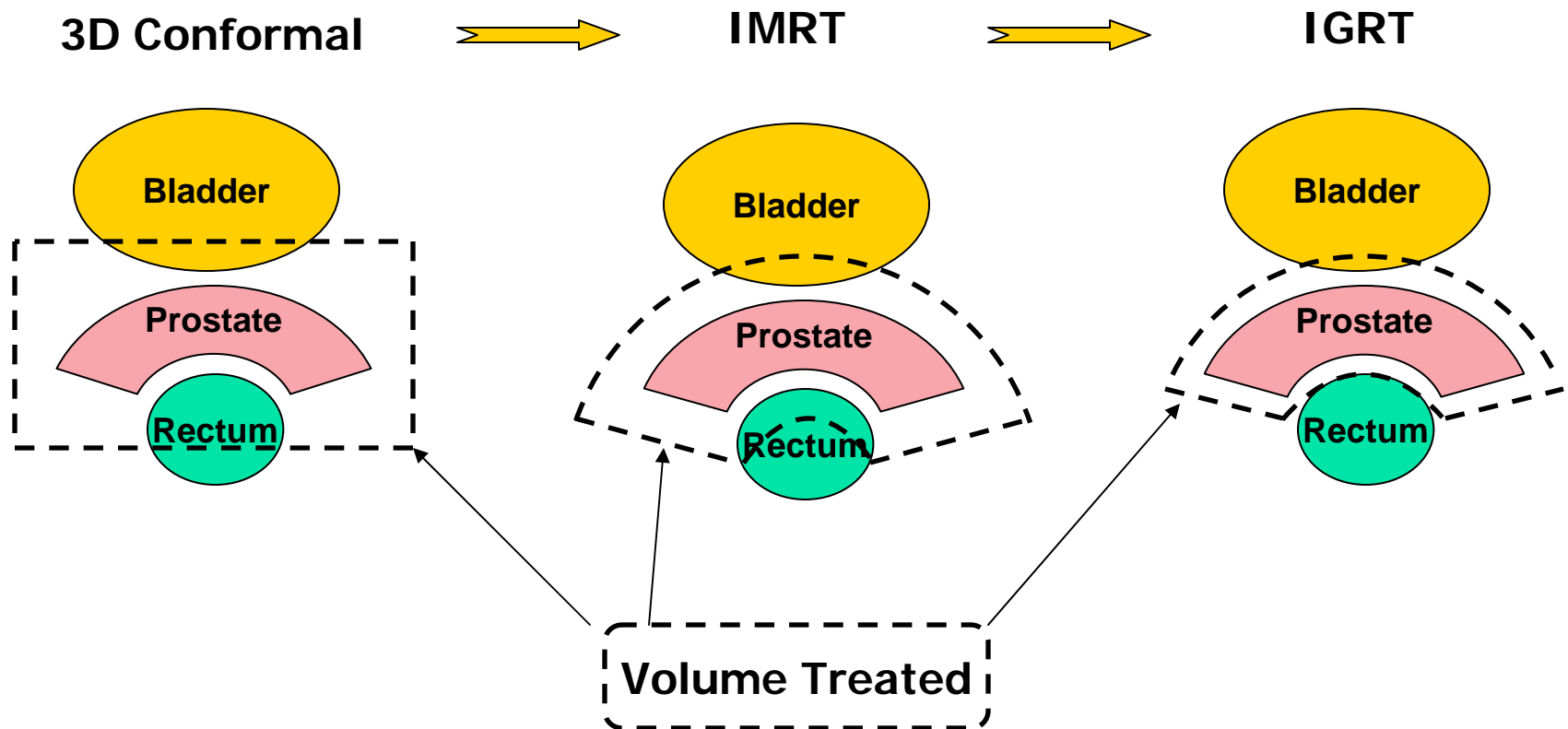
ITV → Customized Target Volume



IGRT can Reduce Internal Margin, Setup Margin, and Margin to OAR



Reduce Treatment Margin





On Board Imager – Varian Trilogy





Image Matching

- 2D-2D matching of OBI images to DRRs
 - Anatomy matching
 - Implanted fiducials
- 3D-3D cone beam CT image match to treatment planning CT images
 - Anatomy matching
 - Structure set alignment of GTV, CTV, PTV, or contoured structures to acquired image



2D-2D Image Match

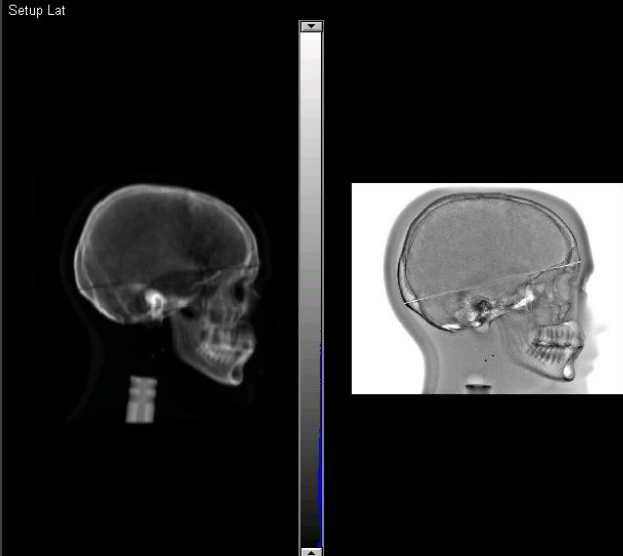
- Orthogonal pair of images
 - AP and Lateral – Brain, H&N
 - Orthogonal Oblique's - Pelvis

Brain: 2D-2D Anatomy Match

Varian Medical Systems

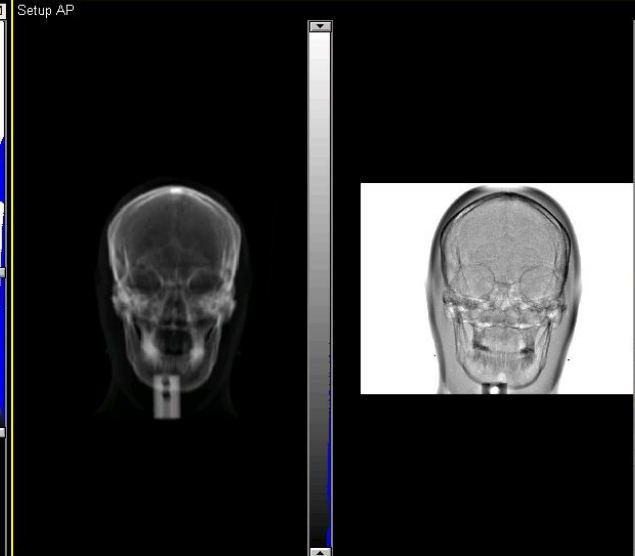
Head, Phantom 2D / 2D Match

Setup Lat



8/4/2004
10:14:31 AM

Setup AP



8/4/2004
10:18:12 AM

kV Imager Position (IEC1217 Scale)				kV Exposure			
	TARGET	ACTUAL	TARGET	ACTUAL			
Gantry Rtn	90.0	90.0	Blade X1	0.0	Site		5 Minute Timer
Source Rtn	0.0	0.0	Blade X2	0.0	Technique		<input type="text"/> <input type="button" value="Reset"/>
SAD	100.0	100.0	Blade Y1	0.0	kV		Anode
kV Imager Vrt	-50.0	-50.0	Blade Y2	0.0	mA		<input type="text"/> % HU
kV Imager Lat	0.0	0.0	<input type="button" value="Track"/> <input type="button" value="Download Axes"/>				Housing
kV Imager Lng	0.0	0.0					<input type="text"/> % HU

All units in cm and degrees

X-Ray Generator locked

1. Acquire 2. Analyze Cancel

Brain: 2D-2D Anatomy Match

Varian Medical Systems

Head, Phantom 2D / 2D Match

Setup Lat Setup AP

Couch Shift (IEC1217 Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	0.0	0.0	0.0	<input checked="" type="checkbox"/> Include	Couch Lat	0.0	0.0	0.0 <input checked="" type="checkbox"/> Include
Couch Lng	50.0	50.0	0.0	<input checked="" type="checkbox"/> Include	Couch Rtn	0.0	0.0	0.0 <input checked="" type="checkbox"/> Include

All units in cm and degrees

Footswitch
Beam Off ?
Reset Shift
Apply Shift

Perform the anatomy match 1. Acquire 2. Analyze Cancel

Pelvis: 2D-2D Anatomy Match

The screenshot displays the Varian Medical Systems software interface for a 2D-2D anatomy match. The main window is titled "2D / 2D Match" and shows two large image windows: "RT FILM-KV" (Right Thorax) and "AP FILM-KV" (Anterior-Posterior). Both images show a pelvis with a green crosshair and a green rectangular box indicating the target area. Below the main images are four smaller reference images: two on the left and two on the right, each with a green crosshair. At the bottom, there is a table for "Couch Shift (VAR_IEC Scale)" with columns for TARGET, ACTUAL, and SHIFT. The table includes checkboxes for "Include" and buttons for "Reset Shift" and "Apply Shift".

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	15.8	15.3	0.5	<input checked="" type="checkbox"/> Include	Couch Lat	998.9	999.3	-0.4 <input checked="" type="checkbox"/> Include
Couch Lng	158.0	158.7	-0.7	<input checked="" type="checkbox"/> Include	Couch Rtn	0.0	0.0	0.0 <input type="checkbox"/> Include

All units in cm and degrees

Perform the anatomy match

1. Acquire 2. Analyze Cancel

Spine: 2D-2D Anatomy Match

Couch Shift (VAR_IEC Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	6.6	6.5	0.1	<input checked="" type="checkbox"/> Include	Couch Lat	997.1	997.2	-0.1 <input checked="" type="checkbox"/> Include
Couch Lng	134.3	134.3	0.0	<input checked="" type="checkbox"/> Include	Couch Rtn	0.1	0.1	0.0 <input type="checkbox"/> Include

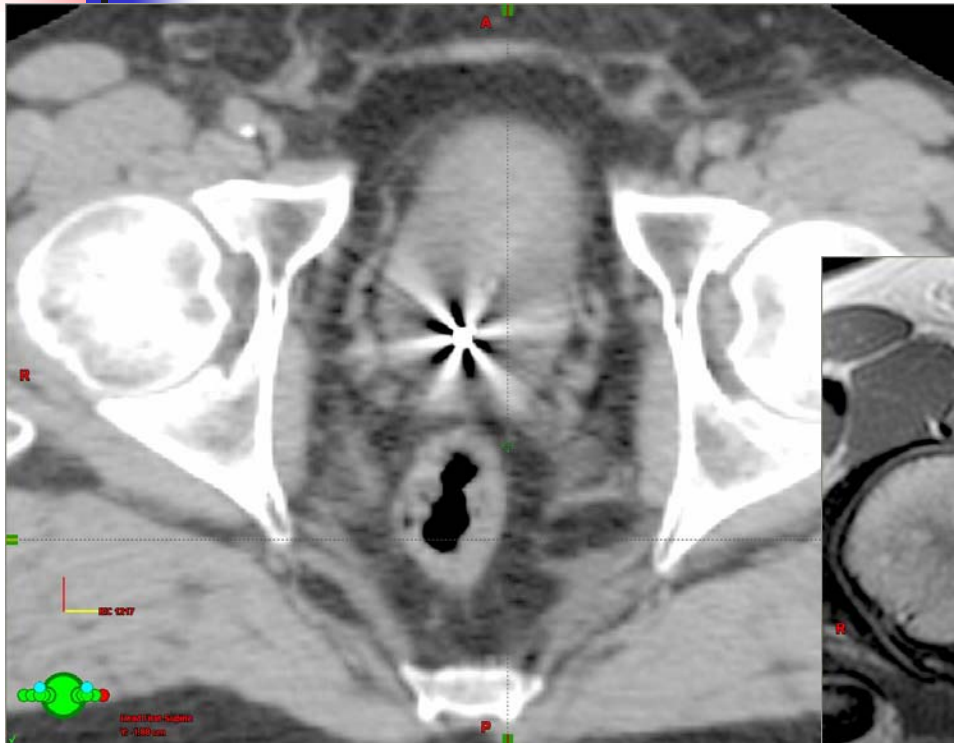
All units in cm and degrees

Perform the anatomy match

1. Acquire 2. Analyze Cancel

Tuesday, May 16, 2006 3:53 PM

Prostate with Implanted Markers



CT



MRI

Prostate Implanted Marker Match

Varian Medical Systems

Marker Match

KV-LAT SU Pro45 - 12/20/2005 13:43 - 270 deg - KV-LAT SU Pro45

KV-AP SU Pro45 - 12/20/2005 13:44 - 0 deg - KV-AP SU Pro45

Couch Shift (VAR_IEC Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	Residual error	
Couch Vrt	12.5	12.7	-0.2	<input checked="" type="checkbox"/> Include	Couch Lat	1.7	1.4	0.3	1.04
Couch Lng	150.3	150.4	-0.1	<input checked="" type="checkbox"/> Include	Couch Rtn	359.5	0.0	-0.5	<input checked="" type="checkbox"/> Include

All units in cm and degrees

Perform the marker match

1. Acquire 2. Detect 3. Analyze Done

Start Varian Medical Syste... 1:50 PM

Prostate Implanted Marker Match

Varian Medical Systems

2D / 2D Match

KV Ap-DRR - KV Lao - 2/22/2007 14:16 - 40 deg

KV R Lat-DRR - KV Rao - 2/22/2007 14:17 - 310 deg

KV Ap-DRR - 2/19/2007 13:11

KV Lao - 2/22/2007 14:16

KV R Lat-DRR - 2/19/2007 13:11

KV Rao - 2/22/2007 14:17

Couch Shift (VAR_IEC Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	11.1	11.1	0.0	<input checked="" type="checkbox"/> Include	Couch Lat	1.1	998.8	<input checked="" type="checkbox"/> Include
Couch Lng	150.7	151.0	-0.3	<input checked="" type="checkbox"/> Include	Couch Rtn	0.00	0.0	<input type="checkbox"/> Include

All units in cm and degrees

Perform the anatomy match

1. Acquire 2. Analyze Cancel

Lung CBCT – before matching

Varian Medical Systems

Lung, ROBERT 3D / 3D Match

Transversal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Transversal - CT_Lung

Head First-Supine
Z: 1.75 cm

Z: 1.75 cm

Frontal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Sagittal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Y: -0.05 cm

X: -0.76 cm

Couch Shift (VAR_IEC Scale, All units in cm and degrees)

Raw Shift Values				Machine Values			
	SHIFT		SHIFT	TARGET	ACTUAL	SHIFT	
Couch Lat	0.0	Couch Pitch	0.0	0.00	0.0	0.0	<input checked="" type="checkbox"/> Include
Couch Lng	0.0	Couch Roll	0.0	0.00	0.0	0.0	<input checked="" type="checkbox"/> Include
Couch Vrt	0.0	Couch Rtn	0.0	0.00	0.0	0.0	<input checked="" type="checkbox"/> Include
		Couch Proj Rtn	0.0	0.00	0.0	0.0	<input checked="" type="checkbox"/> Include

Reset Shift

Apply Shift

Perform the anatomy match

1. Acquire 2. Analyze Cancel

Lung CBCT – matched images

Varian Medical Systems

Lung, ROBERT 3D / 3D Match

Transversal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Transversal - CT_Lung

Head First-Supine
Z: 9.50 cm

Z: 9.50 cm

Frontal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Frontal - CT_Lung

Y: -0.93 cm

Sagittal - CT_Lung - CBCT 2006/10/16 08:50 - 1/1/0001 - 12:00 AM

Sagittal - CT_Lung

X: -0.95 cm

Couch Shift (VAR_JEC Scale, All units in cm and degrees)

Raw Shift Values				Machine Values			
	SHIFT		SHIFT	TARGET	ACTUAL	SHIFT	
Couch Lat	1.9	Couch Pitch	-0.5	Couch Lat	1.9	0.0	1.9 <input checked="" type="checkbox"/> Include
Couch Lng	1.1	Couch Roll	0.8	Couch Lng	1.1	0.0	1.1 <input checked="" type="checkbox"/> Include
Couch Vrt	0.3	Couch Rtn	-0.6	Couch Vrt	0.3	0.0	0.3 <input checked="" type="checkbox"/> Include
		Couch Proj Rtn		Couch Rtn	0.0	0.0	0.0 <input checked="" type="checkbox"/> Include

Reset Shift

Apply Shift

1. Acquire 2. Analyze Cancel

H&N CBCT 3D-3D Match

Varian Medical Systems

3D / 3D Match

Transversal - CT_2-21-06 - ImageUShort554 - 3/2/2006 - 8:49 AM

Transversal - CT_2-21-06

Frontal - CT_2-21-06 - ImageUShort554 - 3/2/2006 - 8:49 AM

Sagittal - CT_2-21-06 - ImageUShort554 - 3/2/2006 - 8:49 AM

Couch Shift (VAR_IEC Scale, All units in cm and degrees)

Raw Shift Values				Machine Values			
	SHIFT		SHIFT	TARGET	ACTUAL	SHIFT	
Couch Lat	-0.2	Couch Pitch	-3.1	Couch Lat	0.3	+0.5	-0.2 <input checked="" type="checkbox"/> Include
Couch Lng	-0.3	Couch Roll	0.2	Couch Lng	79.4	19.6	59.8 <input checked="" type="checkbox"/> Include
Couch Vrt	-0.1	Couch Rtn	-1.5	Couch Vrt	15.9		<input checked="" type="checkbox"/> Include
		Couch Proj Rtn		Couch Rtn	0.0	359.3	0.7 <input checked="" type="checkbox"/> Include

Reset Shift

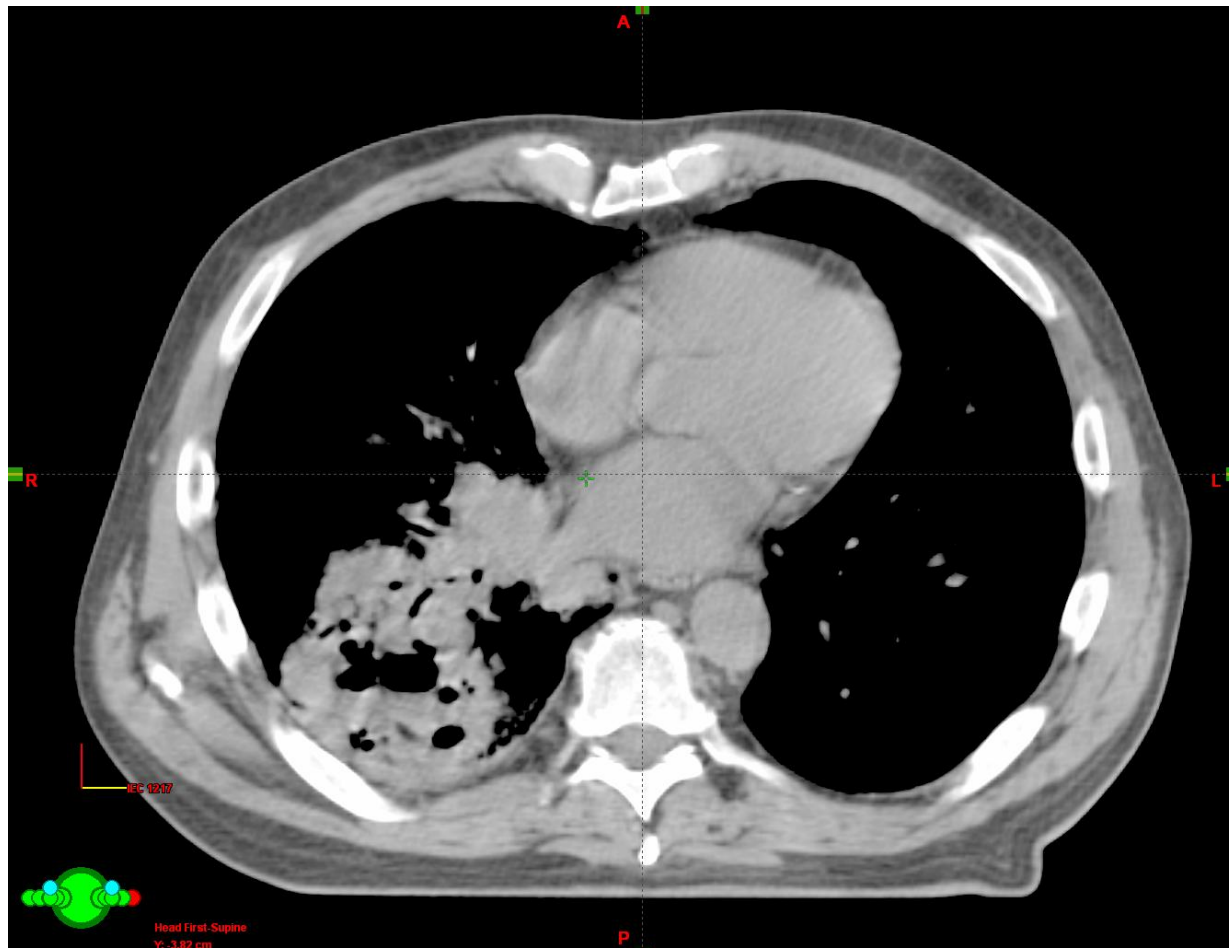
Apply Shift

Perform the anatomy match

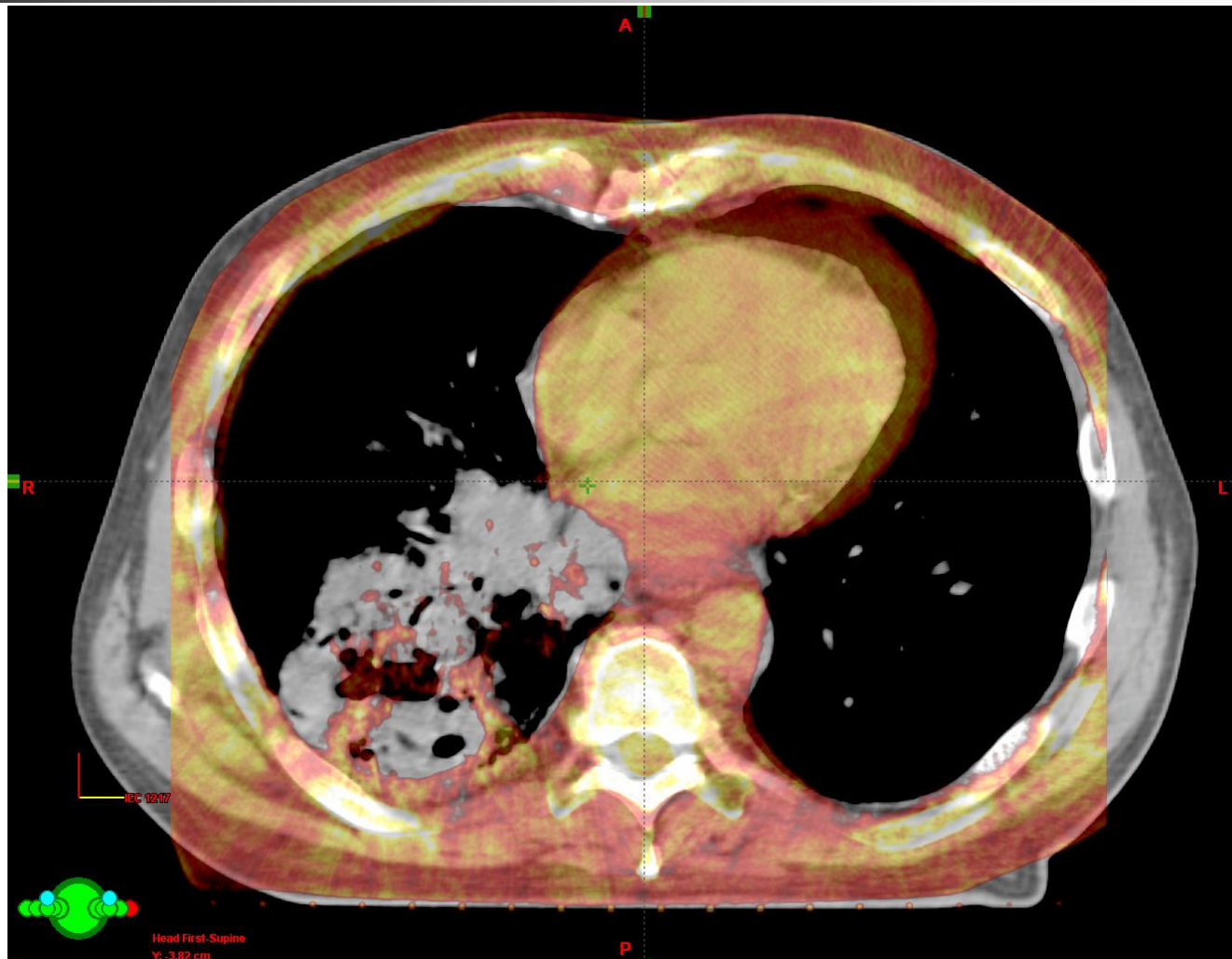
1. Acquire 2. Analyze Done

Start Varian Medical Systeme... breast1 - Paint 8:54 AM

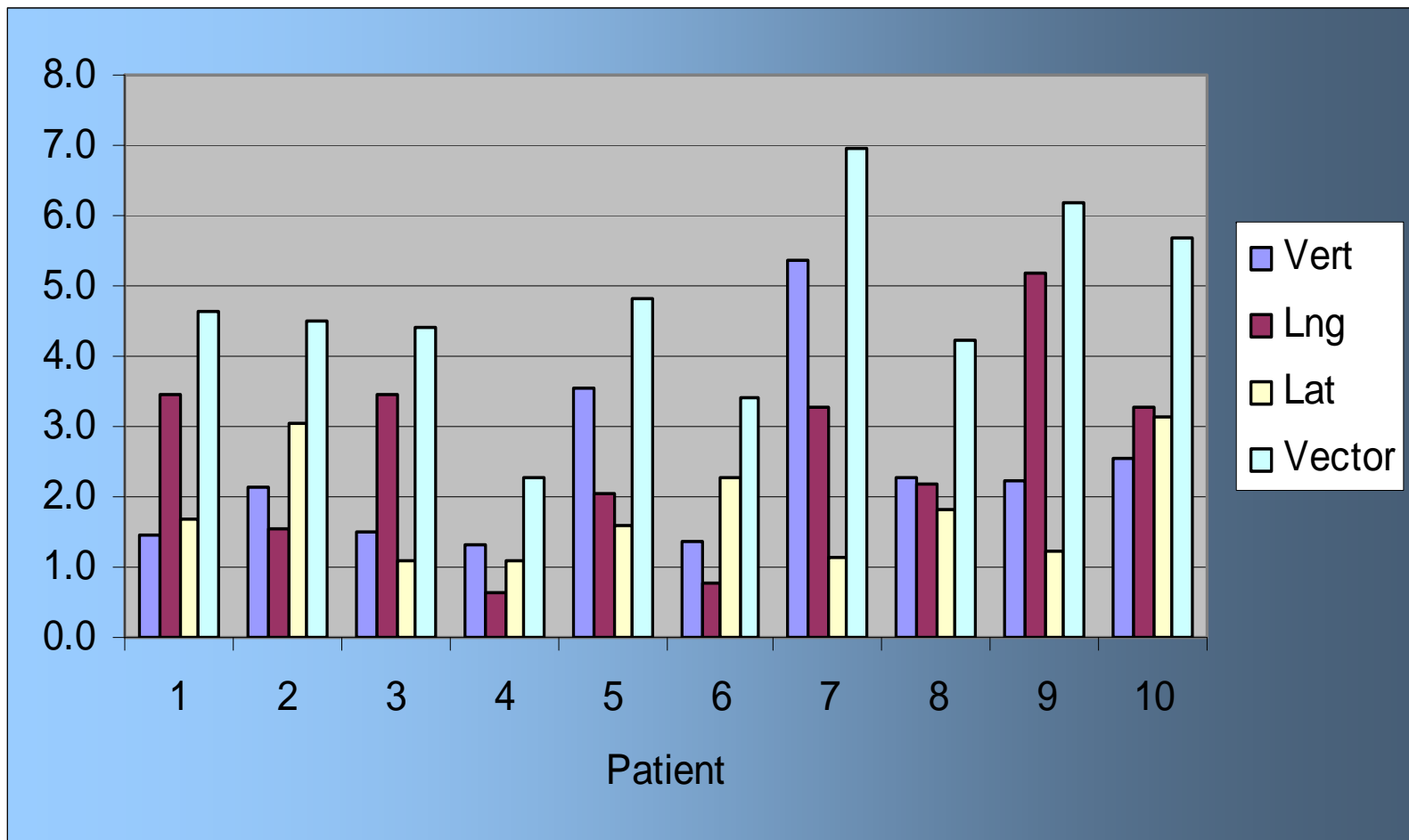
CBCT to Evaluate Tumor Response



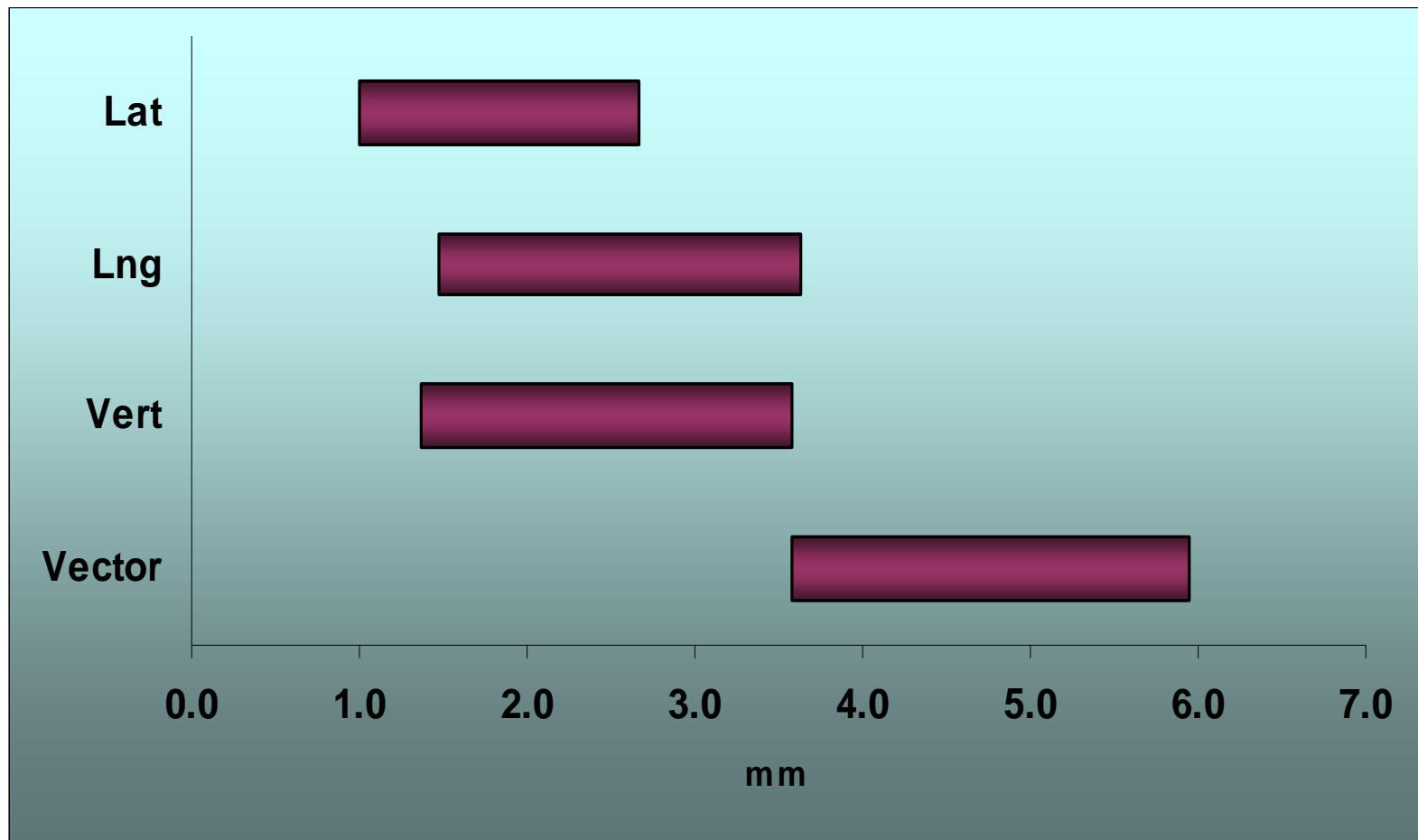
CBCT to Evaluate Tumor Response



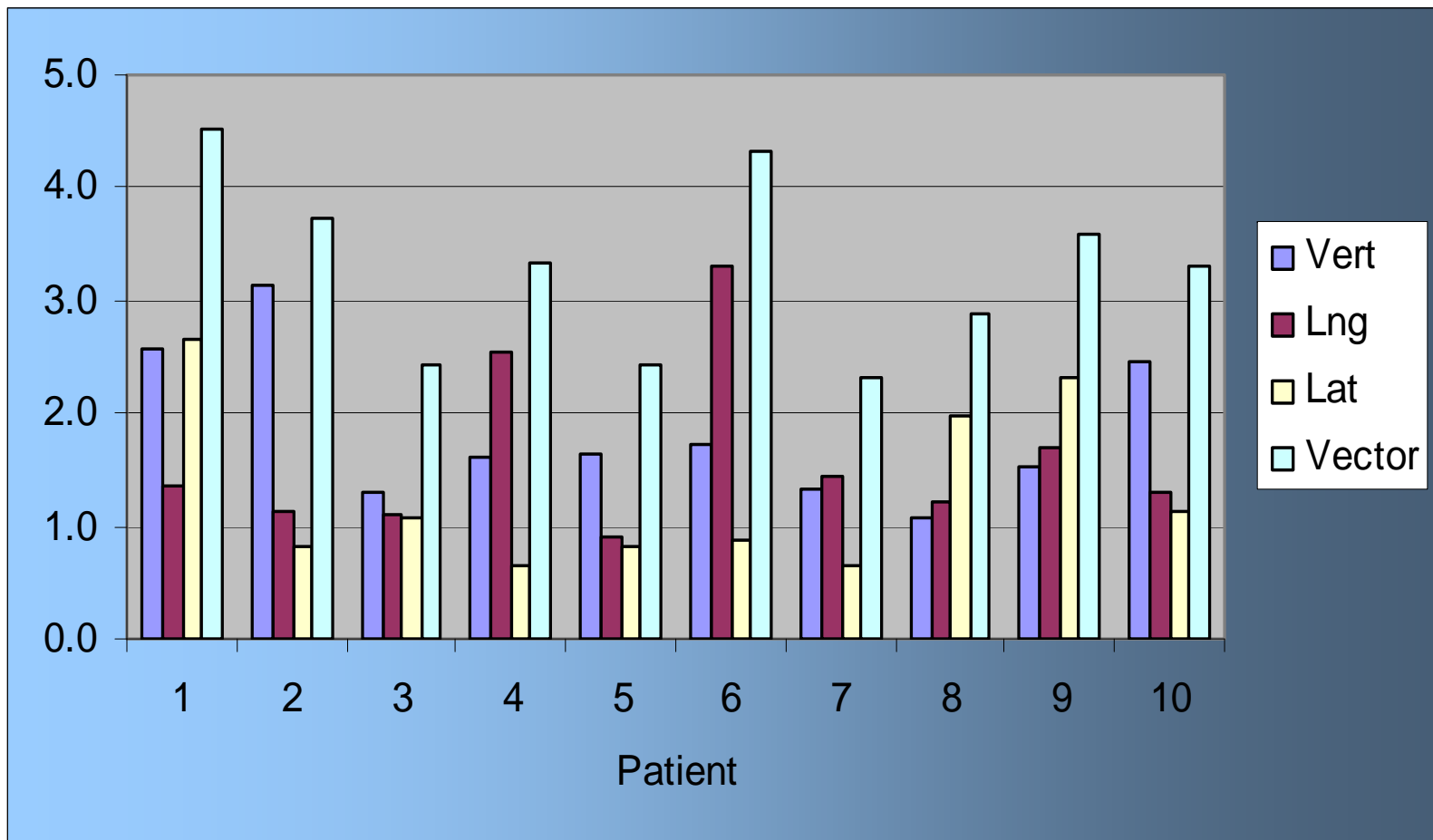
Average Shifts for Prostate



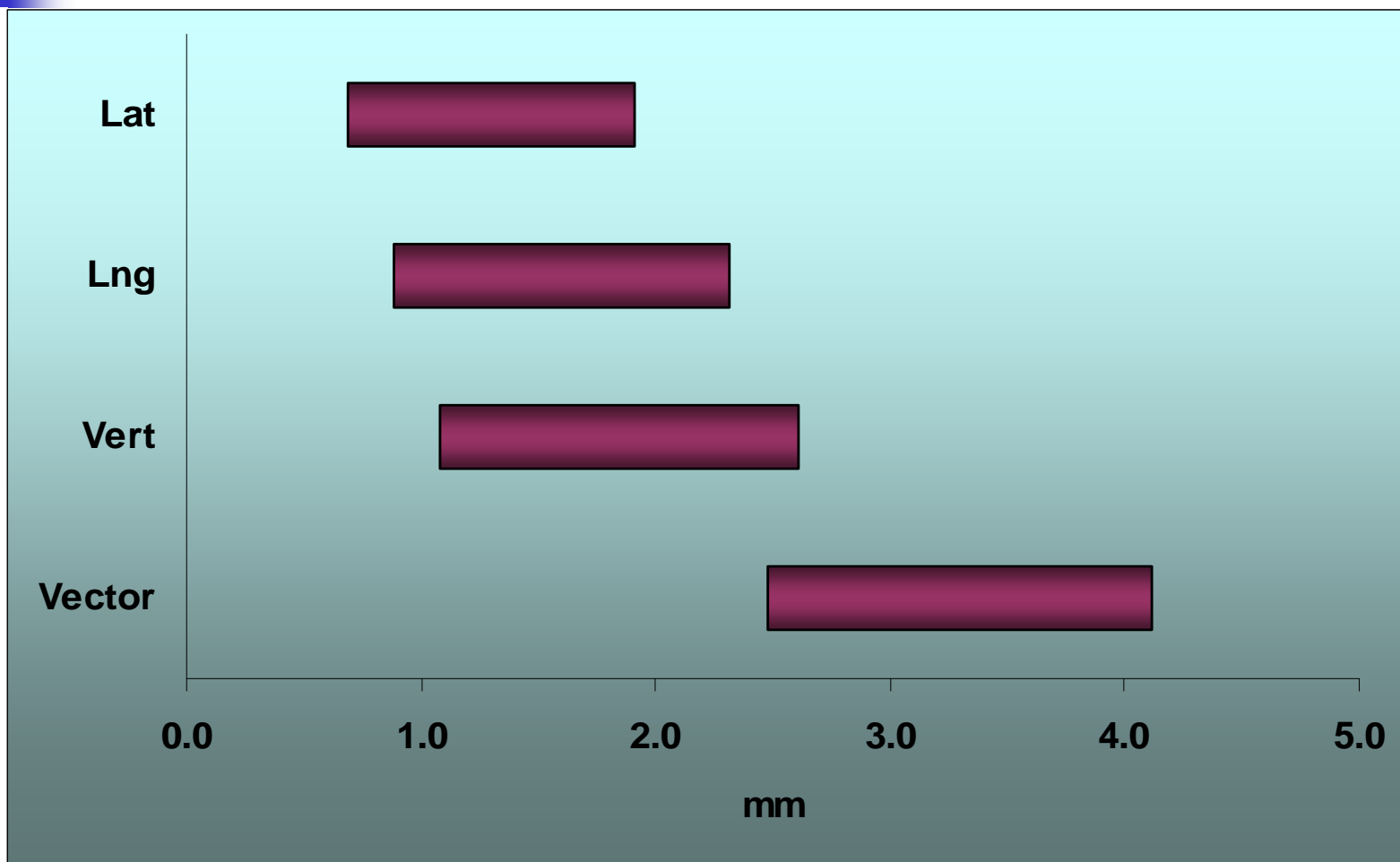
Average Shifts for All Prostate Patients



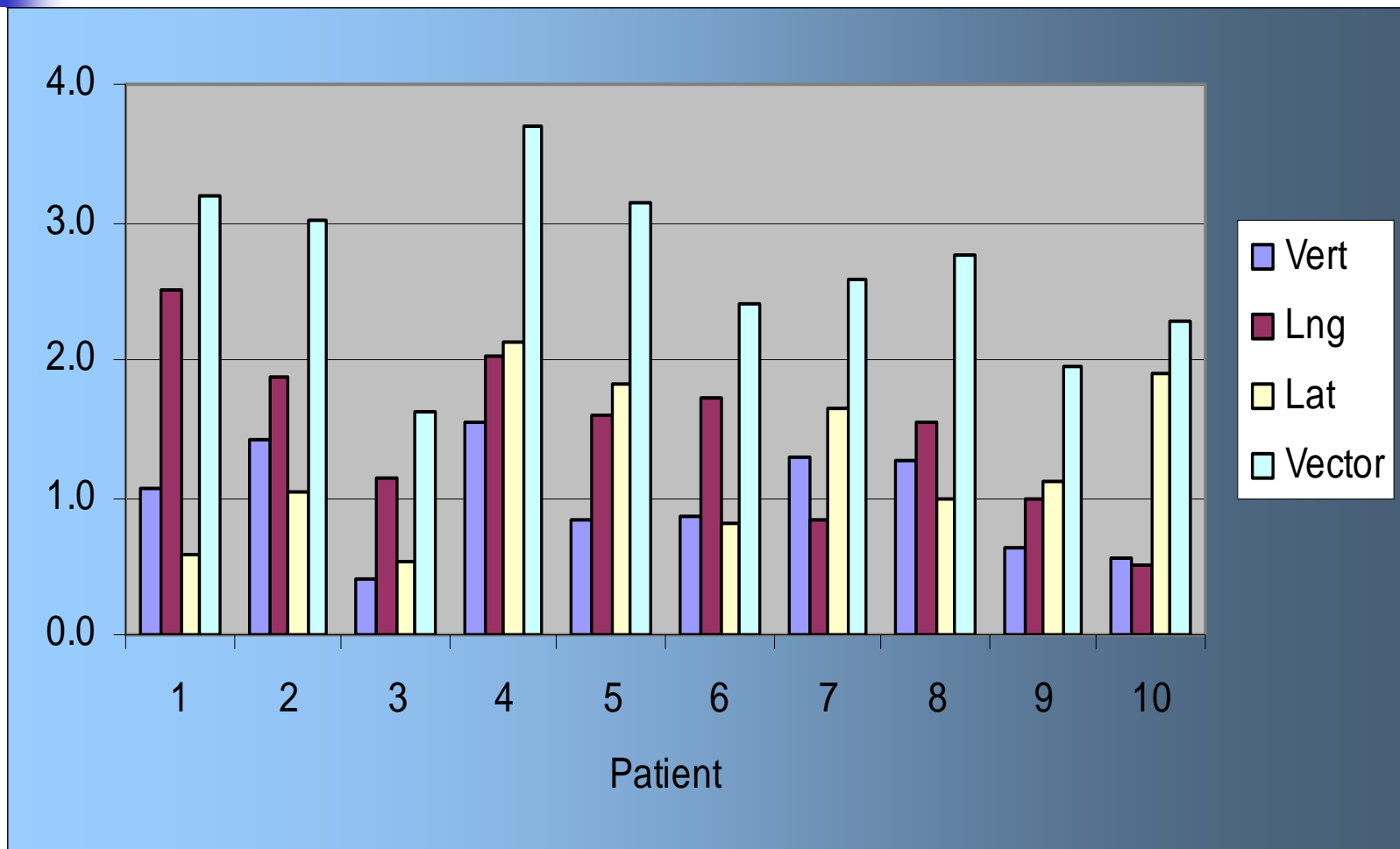
Average Shifts for GBM



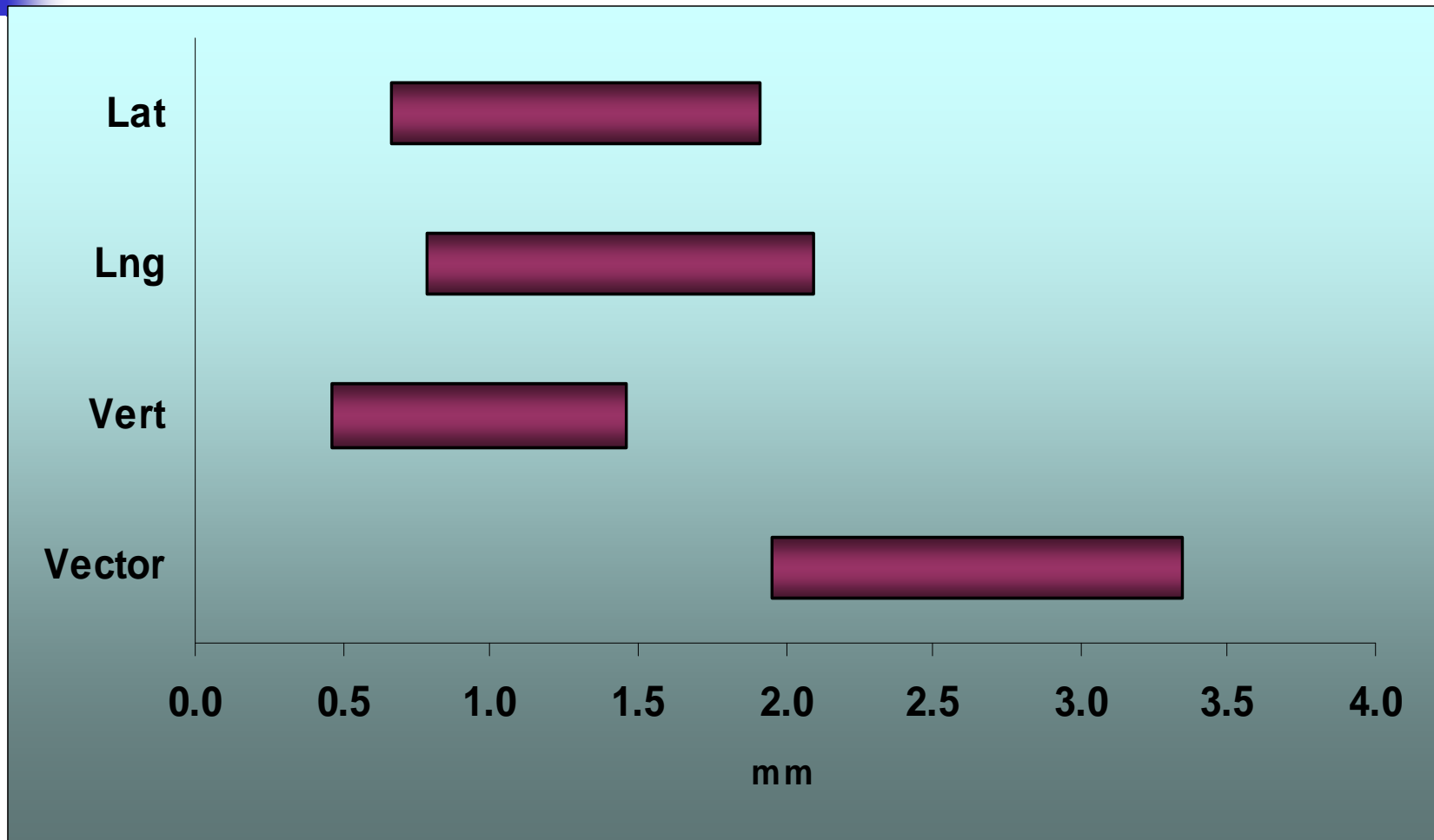
Average Shifts for All GBM Patients



Average Shifts for H&N



Average Shifts for All H&N Patients





Average Shifts + 2 X Standard Deviation

Site	Vert	Lng	Lat	Vector
Prostate	6.9	6.9	5.2	9.5
Prostate Bed	5.4	6.1	4.6	7.9
Brain (GBM)	4.9	4.5	3.7	6.6
H&N	3.0	4.1	3.8	5.4
Lung	5.8	10.1	6.1	11.3
Pancreas	8.6	10.5	6.9	13.3



IGRT Action Levels

– Require Physician/Physics Review

Prostate (Fiducials or Clips)	7 mm
GBM	5 mm
H&N	4 mm
Other (Lung, Pancreas, etc)	10 mm



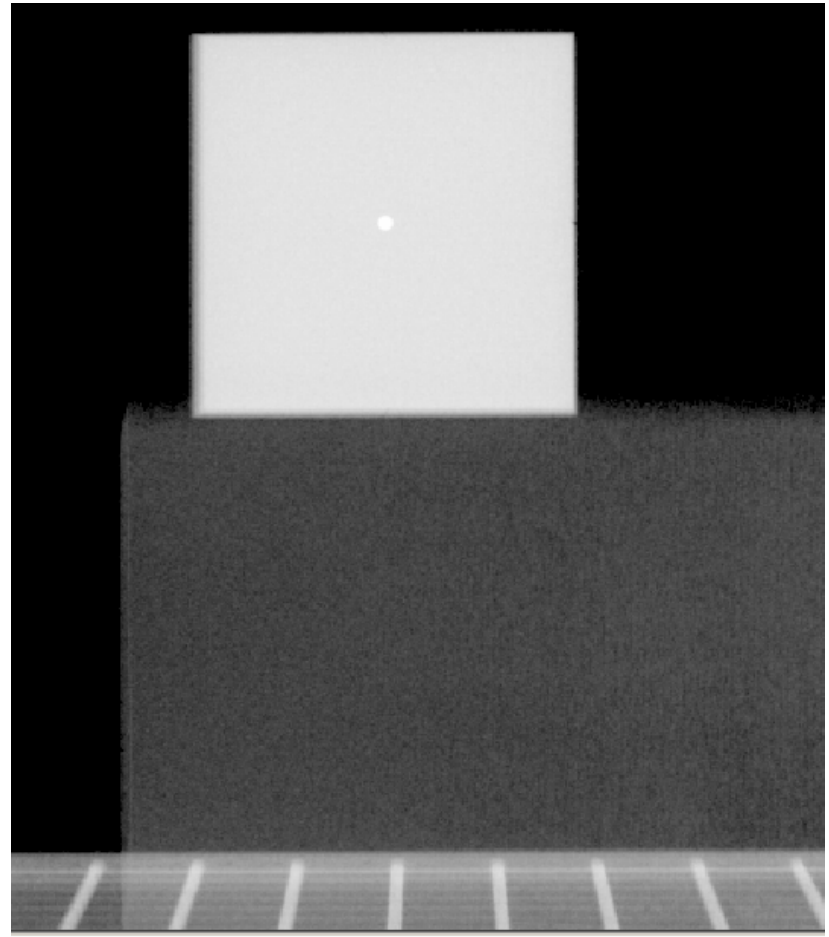
Quality Assurance

- Daily QA
 - Couch shifts with KV images
- Monthly QA
 - KV image – isocenter alignment
- Annual
 - CBCT – isocenter alignment



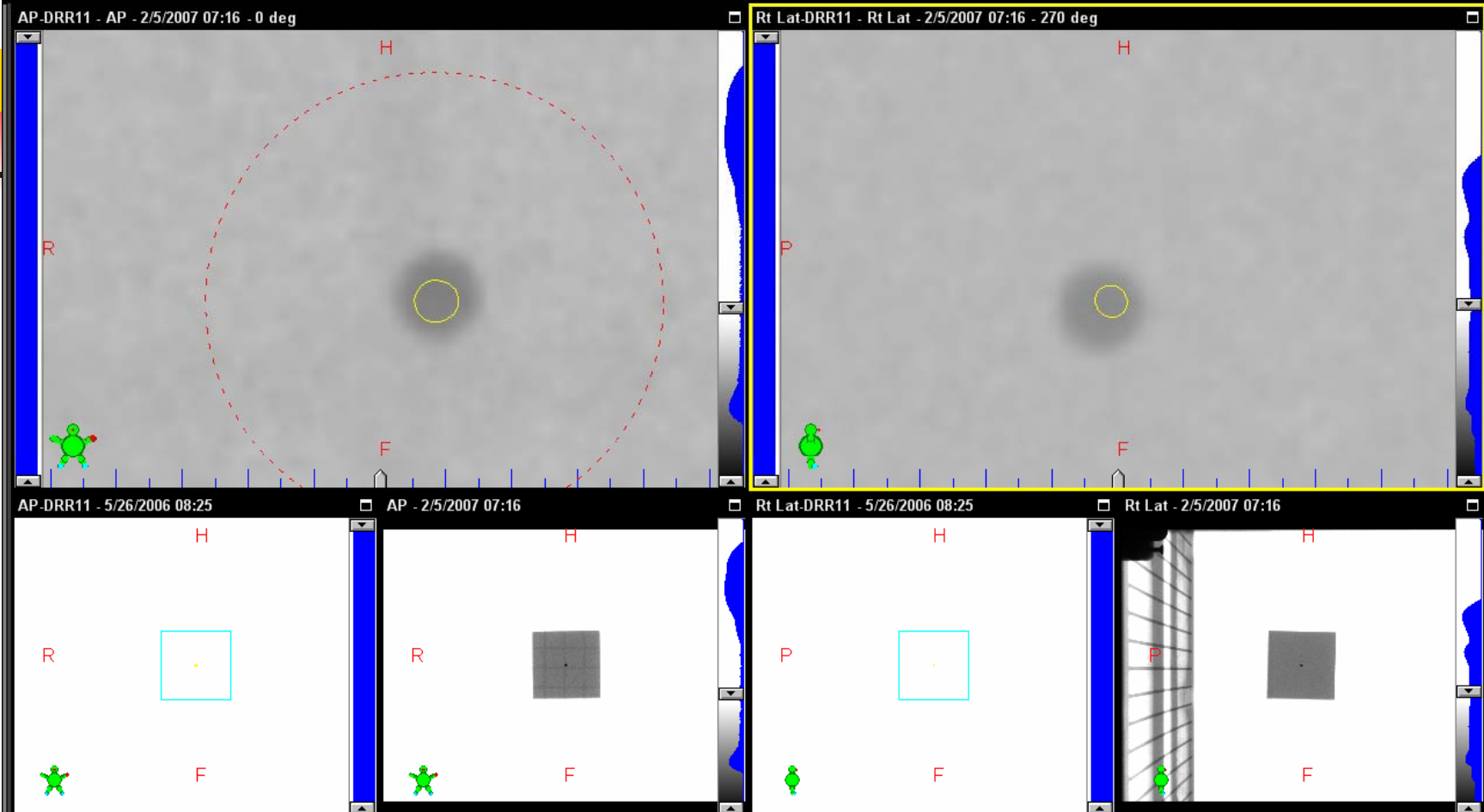
Daily QA

- Couch Shift Accuracy with KV Imaging



OBI, Morning QA

2D / 2D Match



Couch Shift (VAR_JEC Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	9.8	9.9	-0.1	<input checked="" type="checkbox"/> Include	Couch Lat	1.0	1.1	-0.1 <input checked="" type="checkbox"/> Include
Couch Lng	109.1	109.1	0.0	<input checked="" type="checkbox"/> Include	Couch Rtn	0.00	0.0	0.0 <input type="checkbox"/> Include

All units in cm and degrees

Perform the anatomy match

1. Acquire 2. Analyze Done

OBI, Morning QA

2D / 2D Match



Couch Shift (VAR_IEC Scale)

	TARGET	ACTUAL	SHIFT		TARGET	ACTUAL	SHIFT	
Couch Vrt	10.2	10.2	0.0	<input checked="" type="checkbox"/> Include	Couch Lat	1.1	1.1	<input checked="" type="checkbox"/> Include
Couch Lng	112.3	112.3	0.0	<input checked="" type="checkbox"/> Include	Couch Rtn	359.9	359.9	<input type="checkbox"/> Include

Reset Shift
Apply Shift

All units in cm and degrees

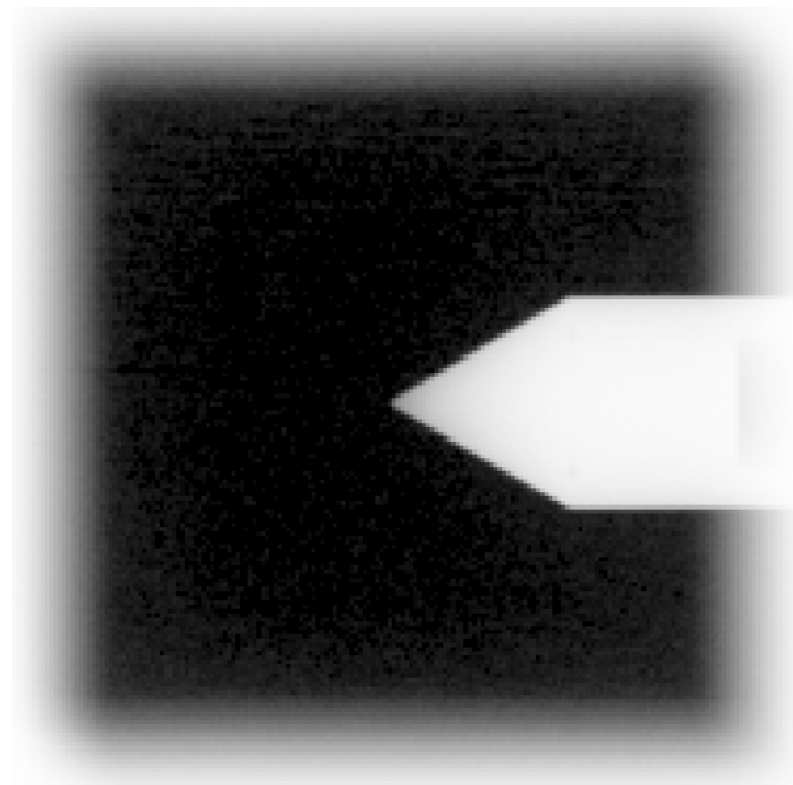
Perform the anatomy match

1. Acquire 2. Analyze Done

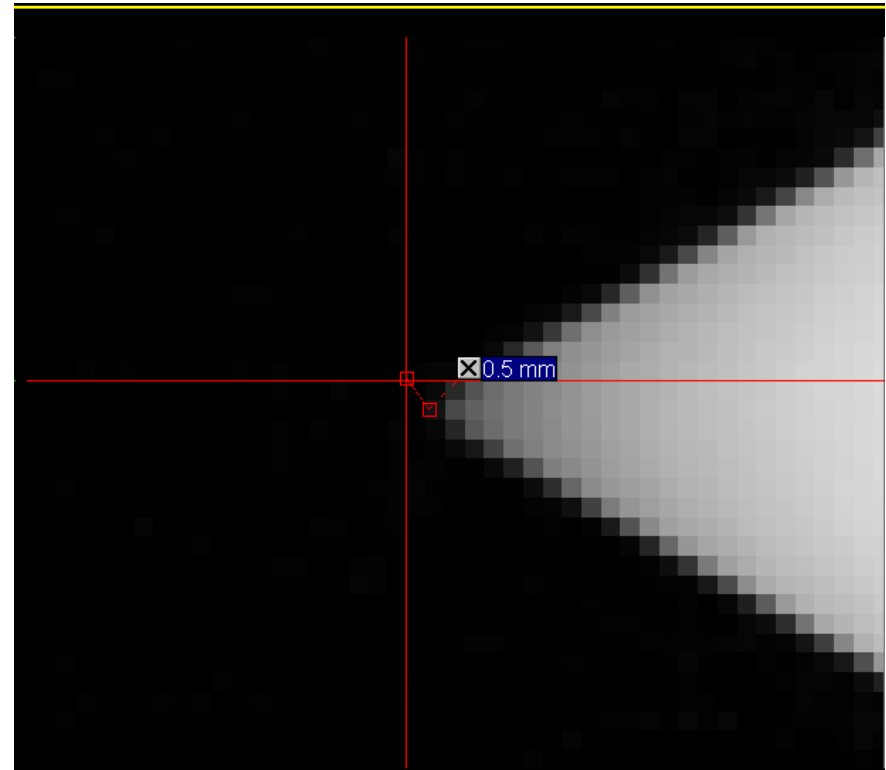
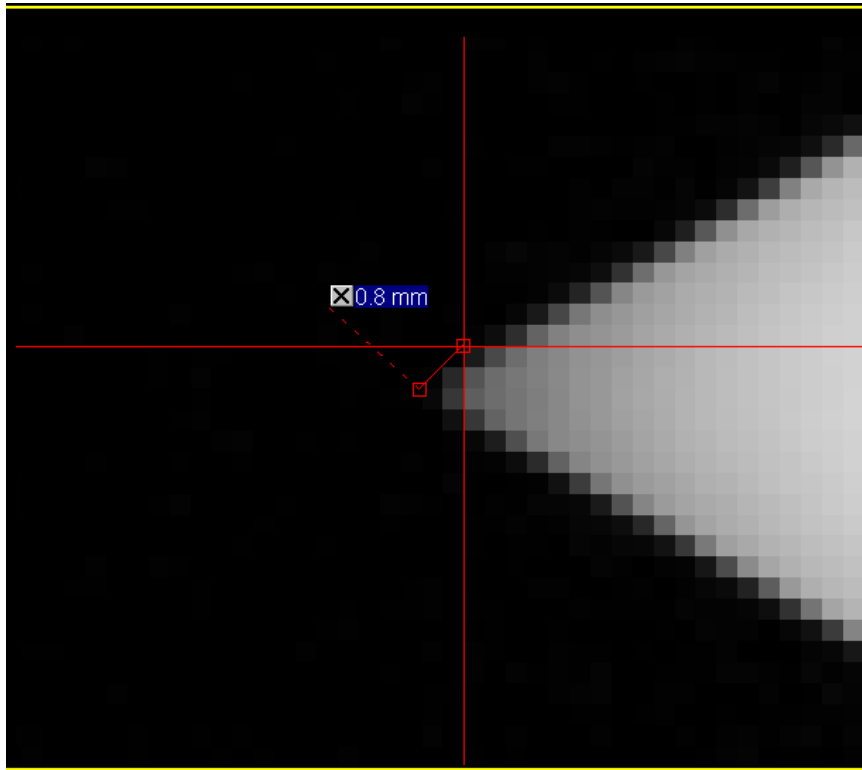


Monthly QA

- KV Image -
Isocenter Alignment



KV Image – Isocenter Alignment





OBI - Some Limitations

- CT resolution and quality of DRR's are limiting factors
- Fiducial artifacts on CT images
- Artifacts on CBCT due to organ motion
- Treatment couch can not tilt and spin



Conclusion

- PET/CT and 4DCT Simulations help us to
 - Delineate target volume and critical structure more accurately
 - Customize, often decrease, internal margin
- On Board Imaging gives us valuable tool to
 - Reduce setup error
 - Track inter-fractional target / organ motion
 - Reduce internal & setup margins
 - Track tumor response – Adaptive Therapy

Adaptive Radiation Therapy, or a Black Hole?





Acknowledgement

Betsy Wang (Physicist)

Julie Gruben (Dosimetrist)

Mike Slechta (Dosimetrist)

Robert Foster (Dosimetrist)

Joy Coldebella (Lead Therapist)

Diane Jennings (Therapist)