Image Registration for Radiation Therapy Applications: Part 2: In-room Volumetric Imaging

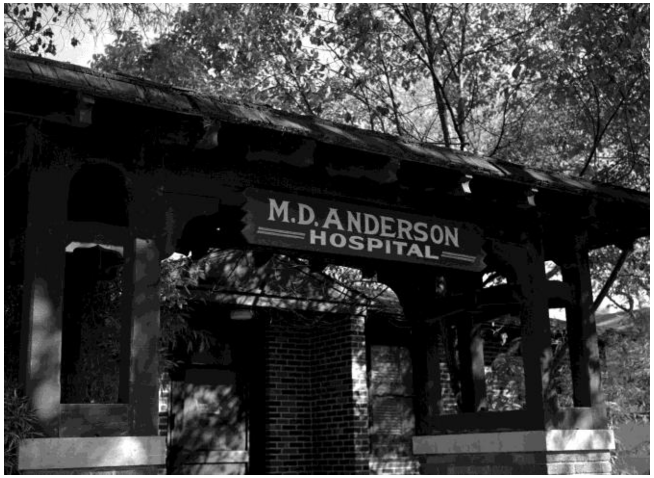
Peter Balter Ph.D

University of Texas M.D. Anderson Cancer Center

Houston, TX, USA

THE UNIVERSITY OF TEXAS
MD Anderson ~~Cancer~~ Center

Making Cancer History®



Disclosure Information
Peter Balter, Ph.D.

I have the following financial relationships to disclose

Grant or research support from:

- Phillips Medical Systems
- National Institute of Health (NIH)
- Varian Associates
- Sun Nuclear Corporation

Employee of

- University of Texas M.D. Anderson Cancer Center

I will **NOT** include discussion of investigational or off-label use of a product in my presentation.

QA: This is important, but I'm not going to talk about it.

Table II. Summary of QC tests recommended for CT-based IGRT systems. Tolerances may change according to expectations, experience and performance.

Frequency	Quality metric	Quality check	Tolerance
Daily	Safety	Collision and other interlocks	Functional
		Warning lights	Functional
	System operation and accuracy	Laser/image/treatment isocentre coincidence OR	±2 mm
		Phantom localization and repositioning with couch shift	±2 mm
Monthly or upon upgrade	Geometric	Geometric calibration maps[a] OR	Replace/refresh
		kV/MV/laser alignment	±1 mm
		Couch shifts: accuracy of motions	±1 mm
	Image quality	Scale, distance, and orientation accuracy[a]	Baseline
		Uniformity, noise[a]	Baseline
		High contrast spatial resolution[a]	≤ 2 mm (or ≤ 5 lp/cm)
		Low contrast detectability[a]	Baseline
If used for dose calculation	Image quality	CT number accuracy and stability[a]	Baseline
Annual	Dose	Imaging dose	Baseline
	Imaging system performance	X-ray generator performance (kV systems only): tube potential, mA, ms accuracy, and linearity	Baseline
	Geometric	Anteroposterior, mediolateral, and craniocaudal orientations are maintained (upon upgrade from CT to IGRT system)	Accurate
	System operation	Long and short term planning of resources (disk space, manpower, etc.)	Support clinical use and current imaging policies and procedures

a,

Quality assurance for image-guided radiation therapy utilizing CT-based technologies: A report of the AAPM TG-179

Jean-Pierre Bissonnette[a)]
Task Group 179, Department of Radiation Physics, Princess Margaret Hospital, University of Toronto, Toronto, Ontario, Canada, M5G 2M9

Learning Objectives

- Understand the registration between image guidance image set and treatment planning CT.
- Recognize the limitations and clinical applications of image guidance registration.
- Acknowledge the advantages and disadvantages for selection of ROI
    - Dose as an ROI
- Discuss requirements of communication and means of communication among the treatment team for IGRT.

In-room volumetric imaging

- Allows direct visualization of many type of tumors (but not all)
- CT-on Rails
- CBCT
- MVCBCT
- MVCT

Available technologies for in-room CT

TABLE I. Commercially available CT-based IGRT systems.

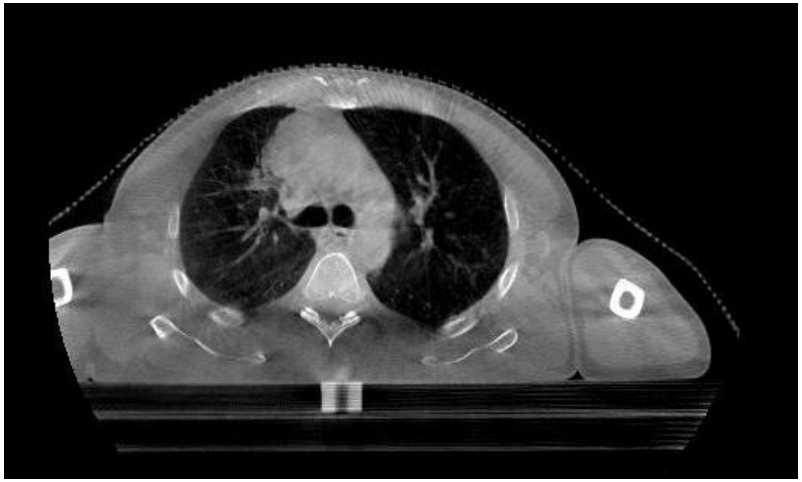
Make and model		Elekta XVI	Varian On-Board Imager	Siemens Artiste	TomoTherapy	Siemens Primatom
Imaging configuration		kV-CBCT	kV-CBCT	MV-CBCT	MVCT	kVCT-on rails
Field of view		$50 \times 50 \times 25.6$	$45 \times 45 \times 17$	$40 \times 40 \times 27.4$	40 cm	50 cm
Correction method	Translation	Automatic couch motion	Automatic couch motion	Automatic couch motion	Automatic in 2 directions	Manual couch motion
	Rotation	Optional	None	None	Optional	Optional
Geometric accuracy		Submillimeter	Submillimeter	Submillimeter	Submillimeter	Submillimeter
Dose (cGy)		0.1–3.5	0.2–2.0	3–10	0.7–3.0	0.05–1
Image acquisition and reconstruction time		2 min	1.5 min	1.5 min	5 s per slice	3 s per sec

Quality assurance for image-guided radiation therapy utilizing CT-based technologies: A report of the AAPM TG-179

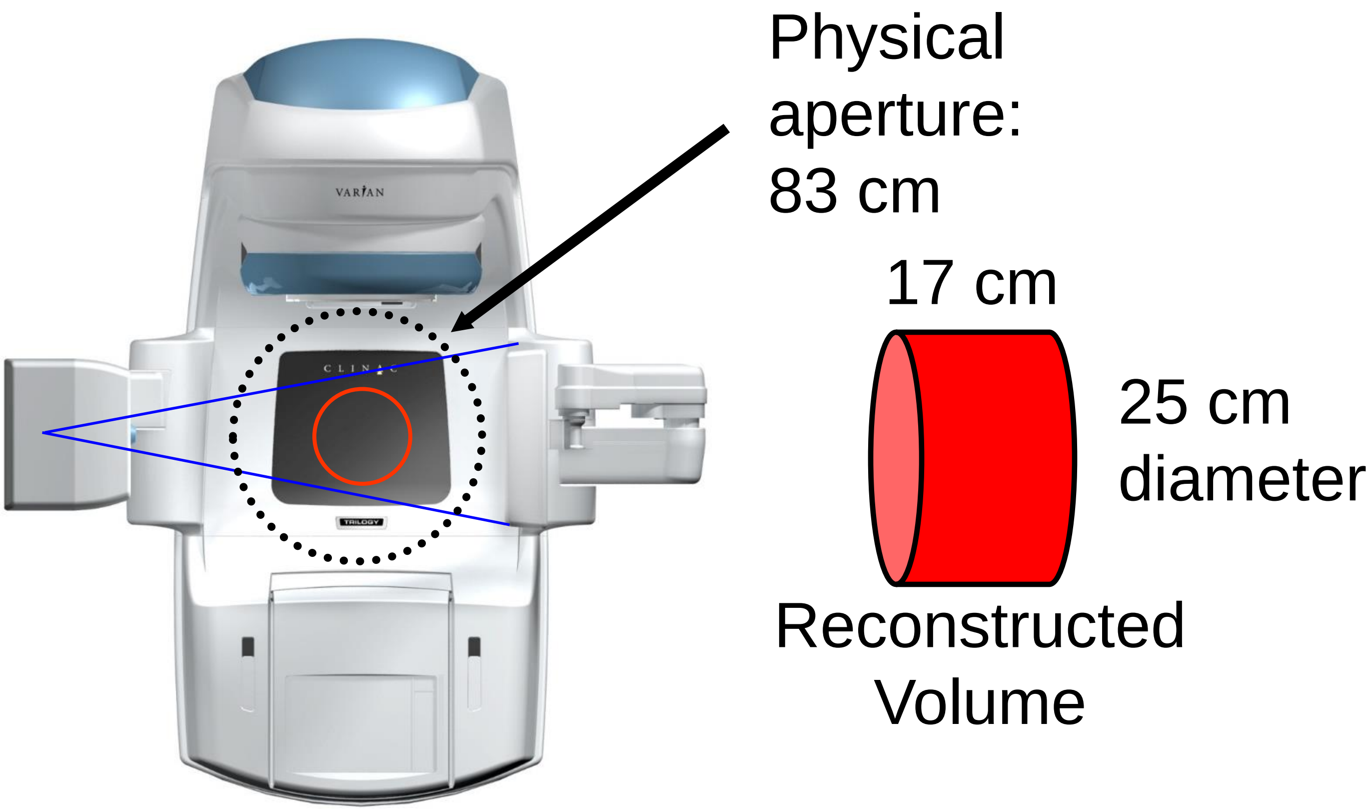
Jean-Pierre Bissonnette[a]
Task Group 179, Department of Radiation Physics, Princess Margaret Hospital, University of Toronto, Toronto, Ontario, Canada, M5G 2M9

In-room CT- Cone Beam CT

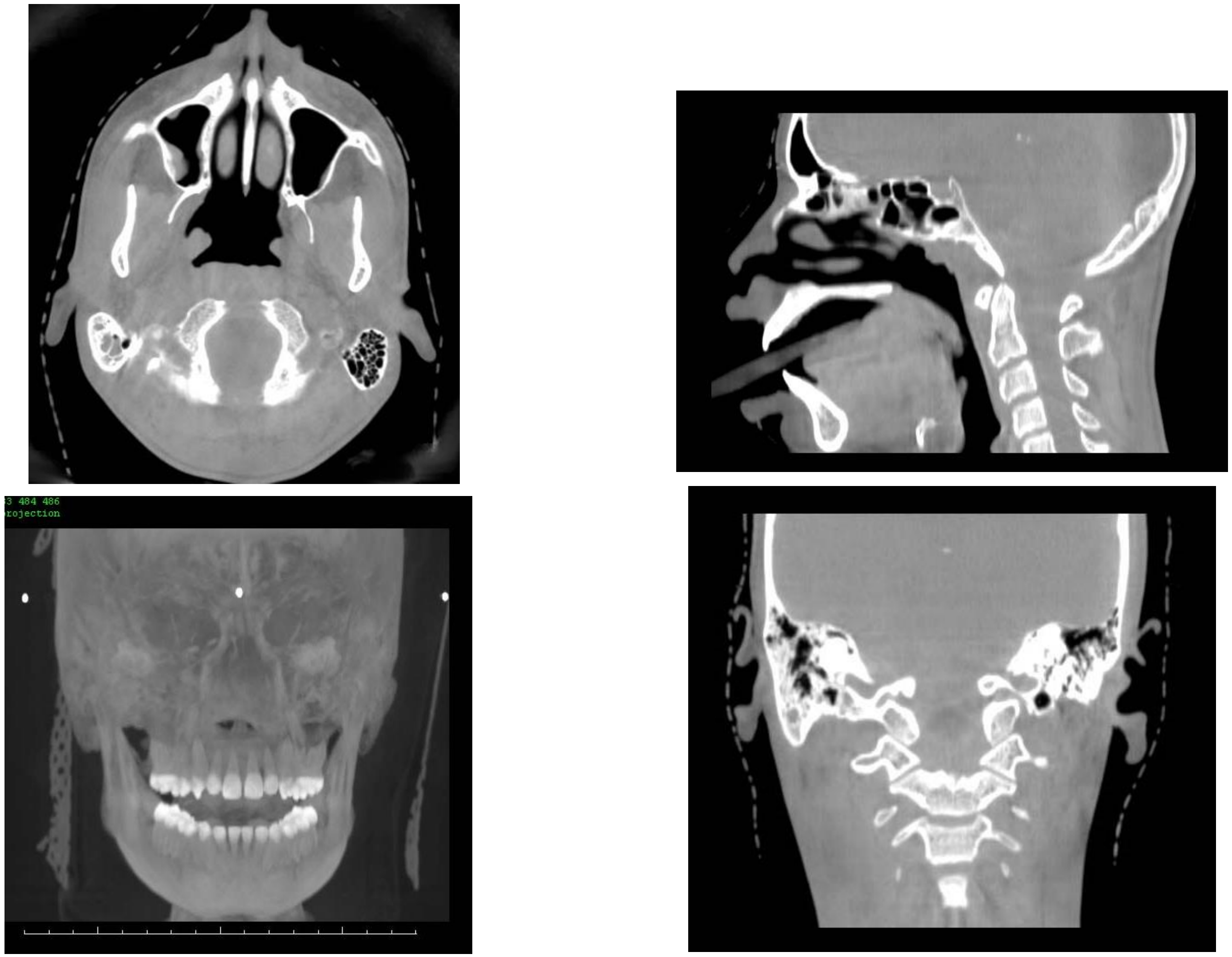
- X-ray tube and flat panel imager are mounted on the linac gantry
- In one rotation around the patient (1 min) 400 projection images can be acquired
- These can be reconstructed into a short CT volume



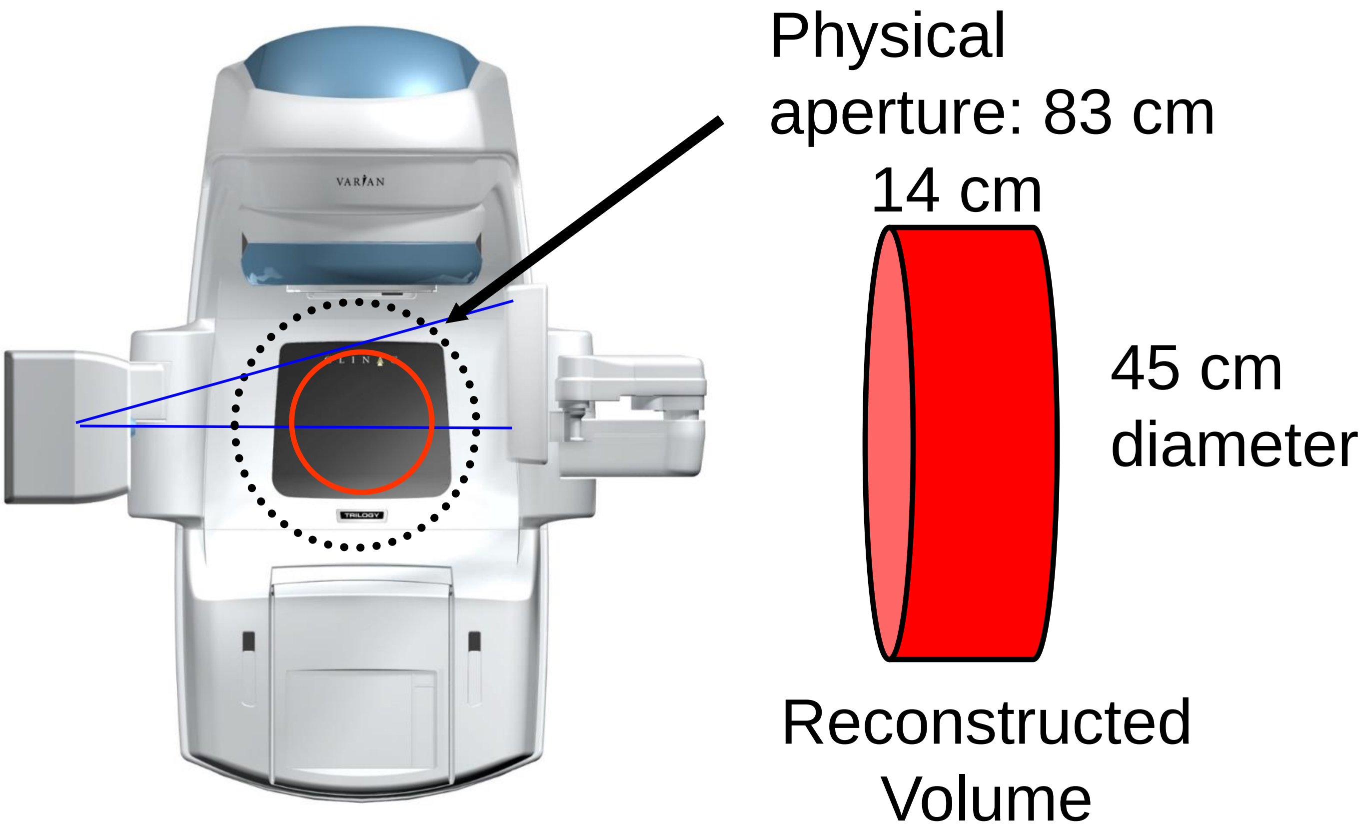
Acquisition – Head Scan



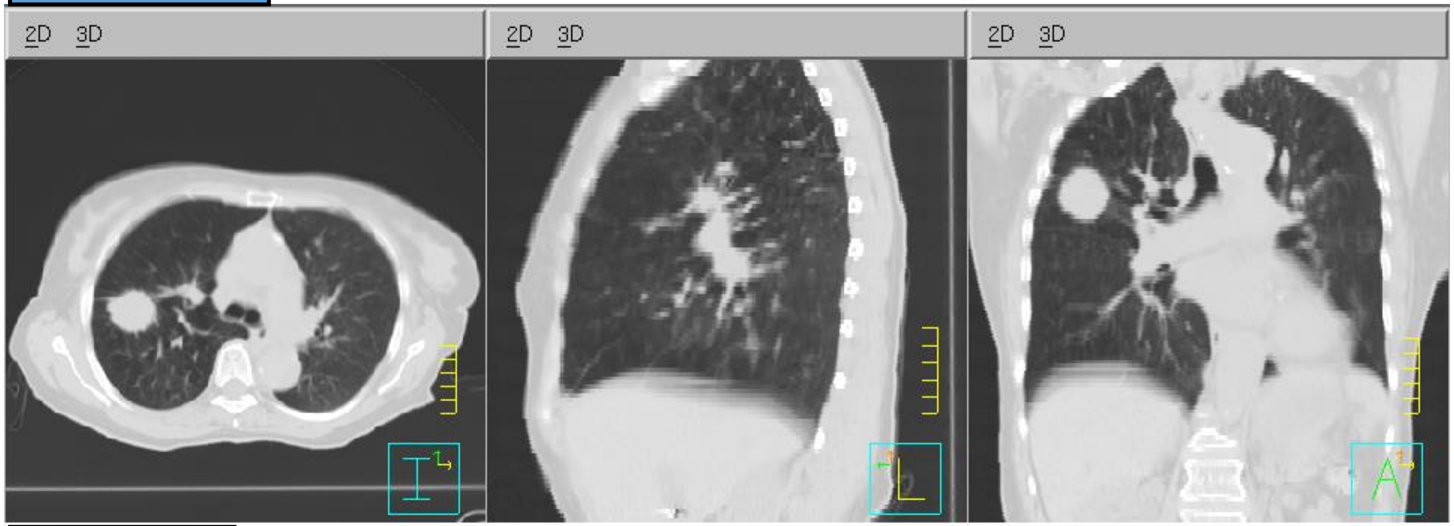
Cone Beam CT images



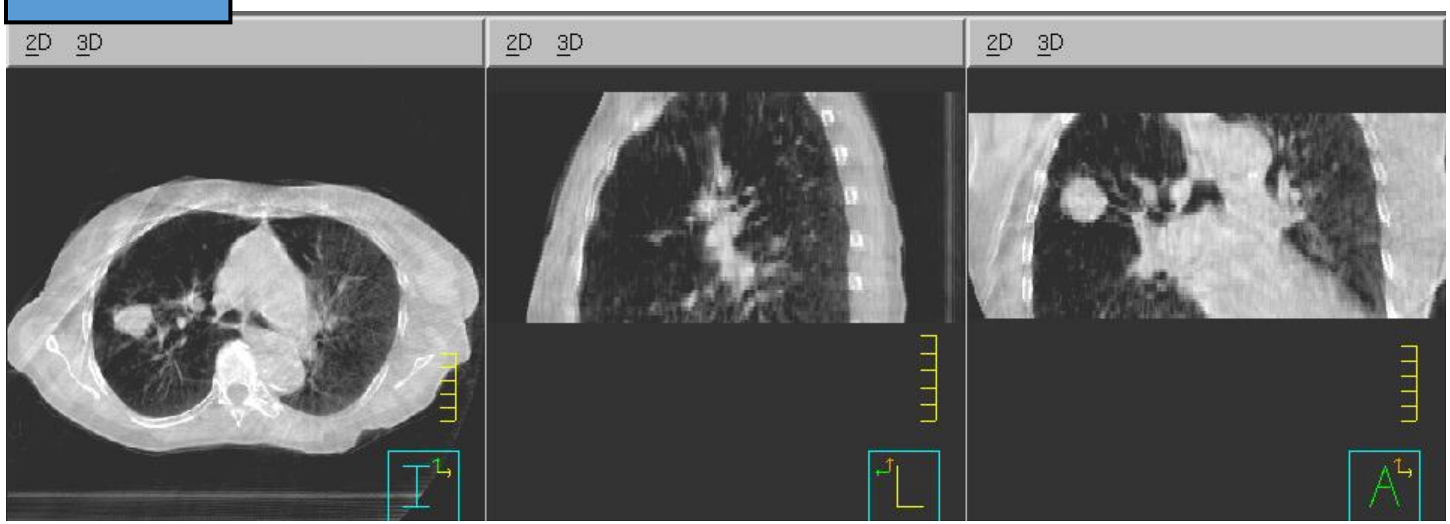
Acquisition – Body Scan



CT

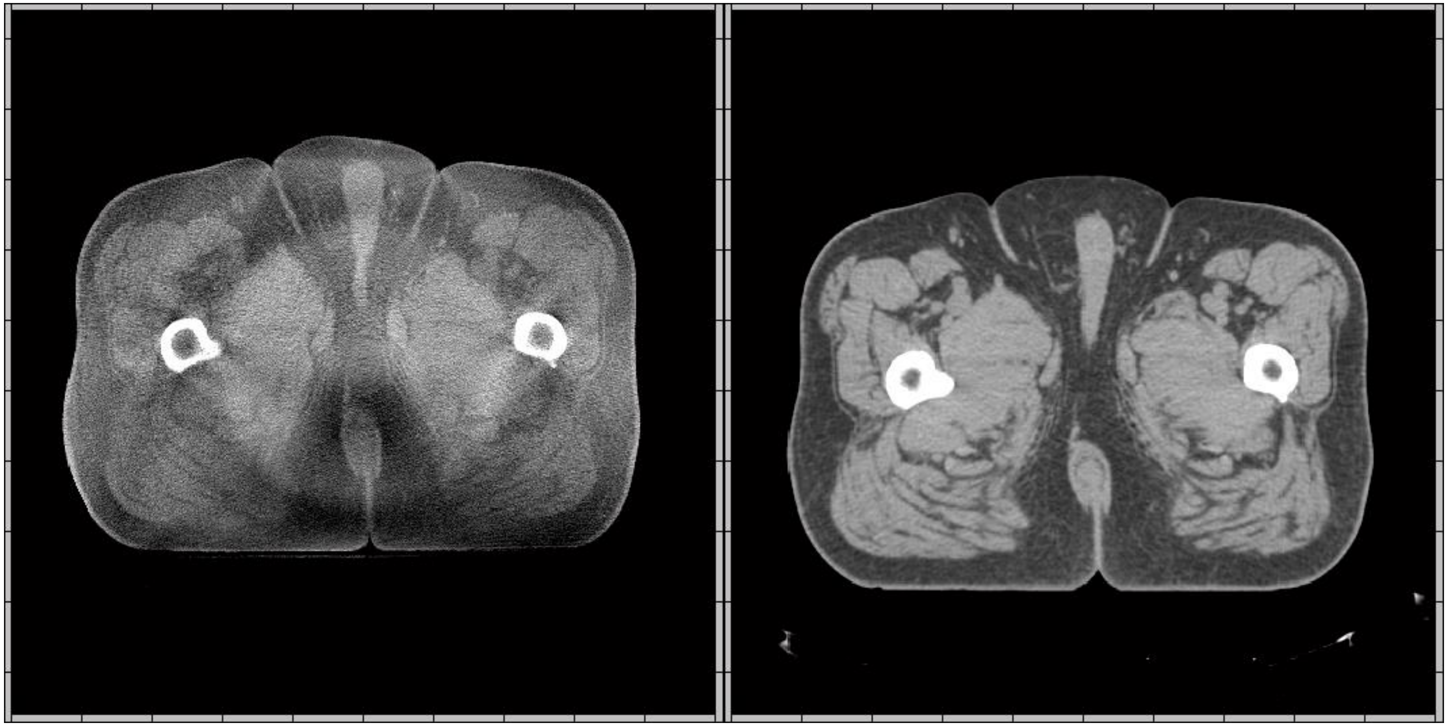


CBCT

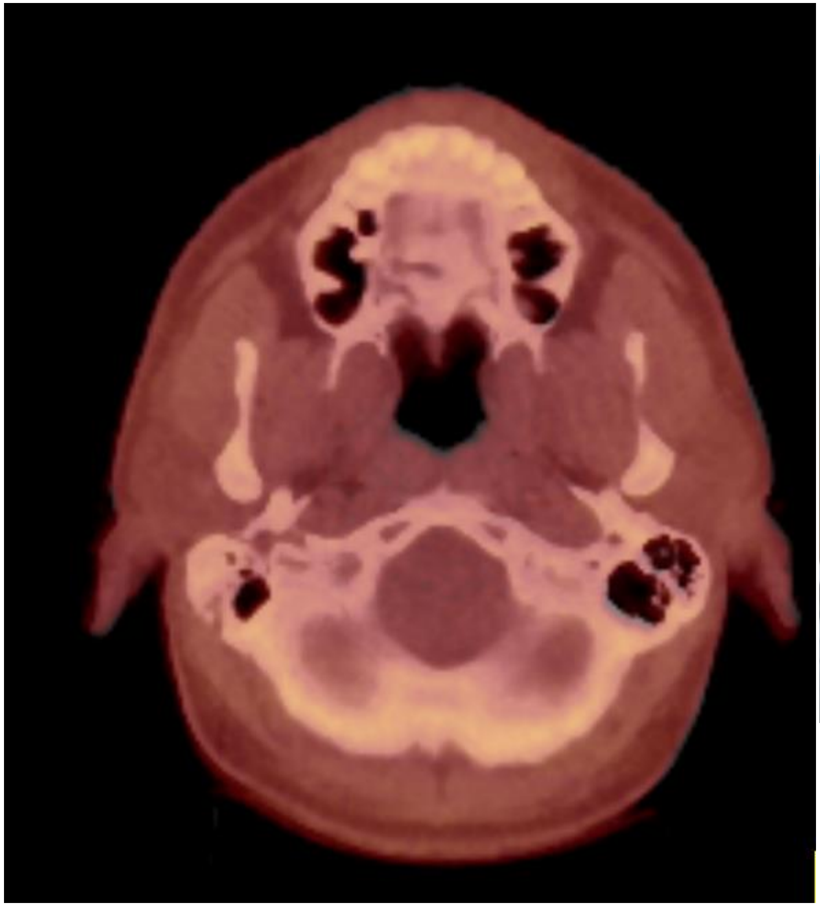


Lindsay

Cone Beam CT – Large GU patient (330 lbs)



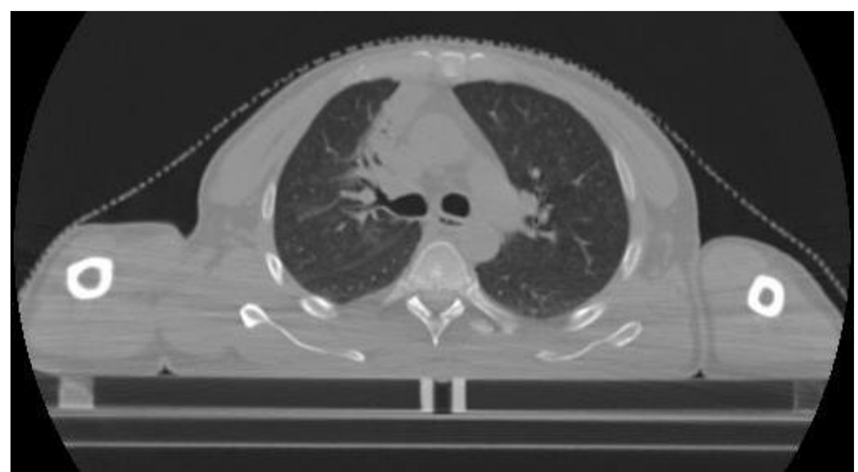
Cone Beam CT can also be generated using MV x-rays
(Example from a Siemens Machine)

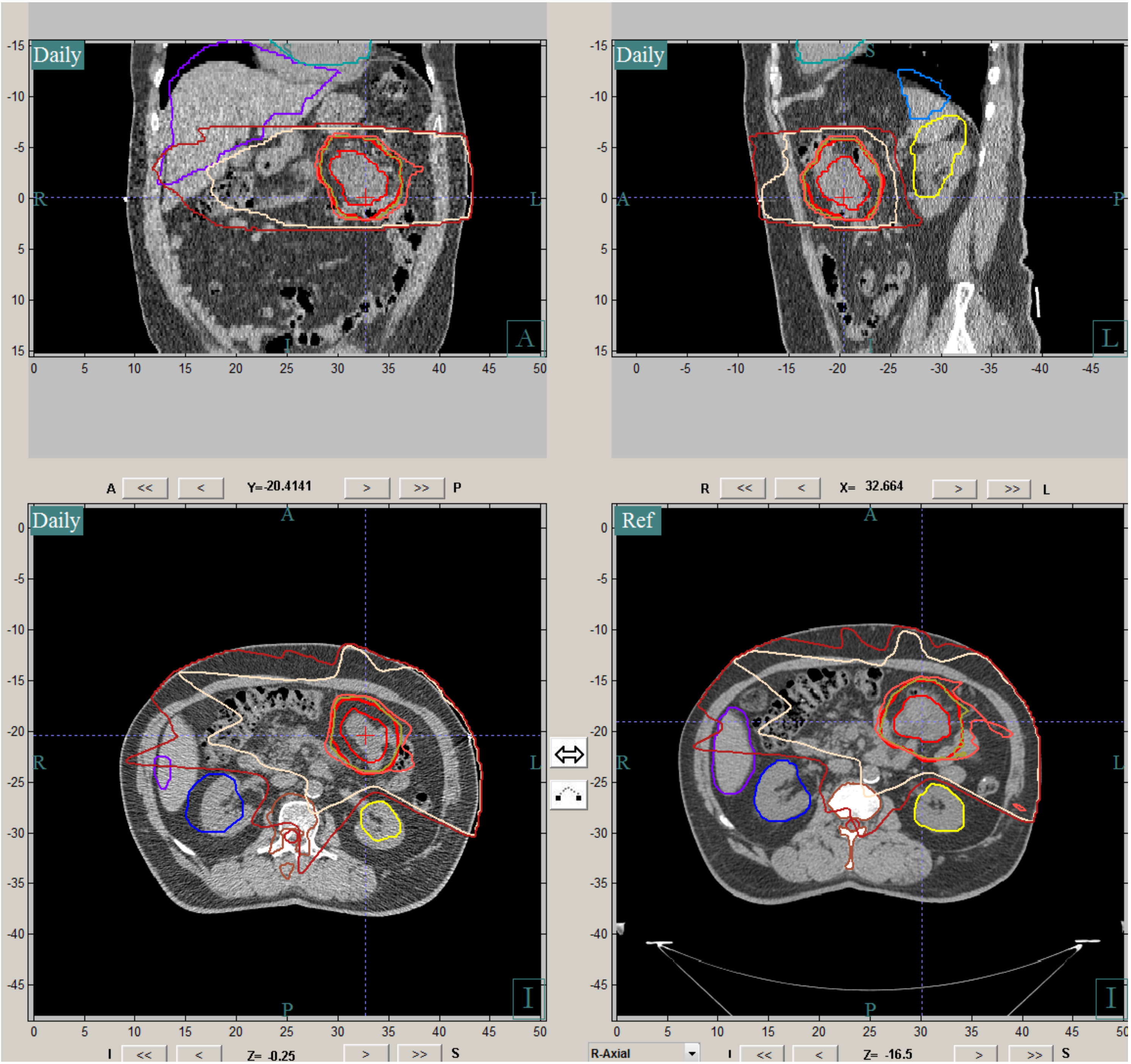


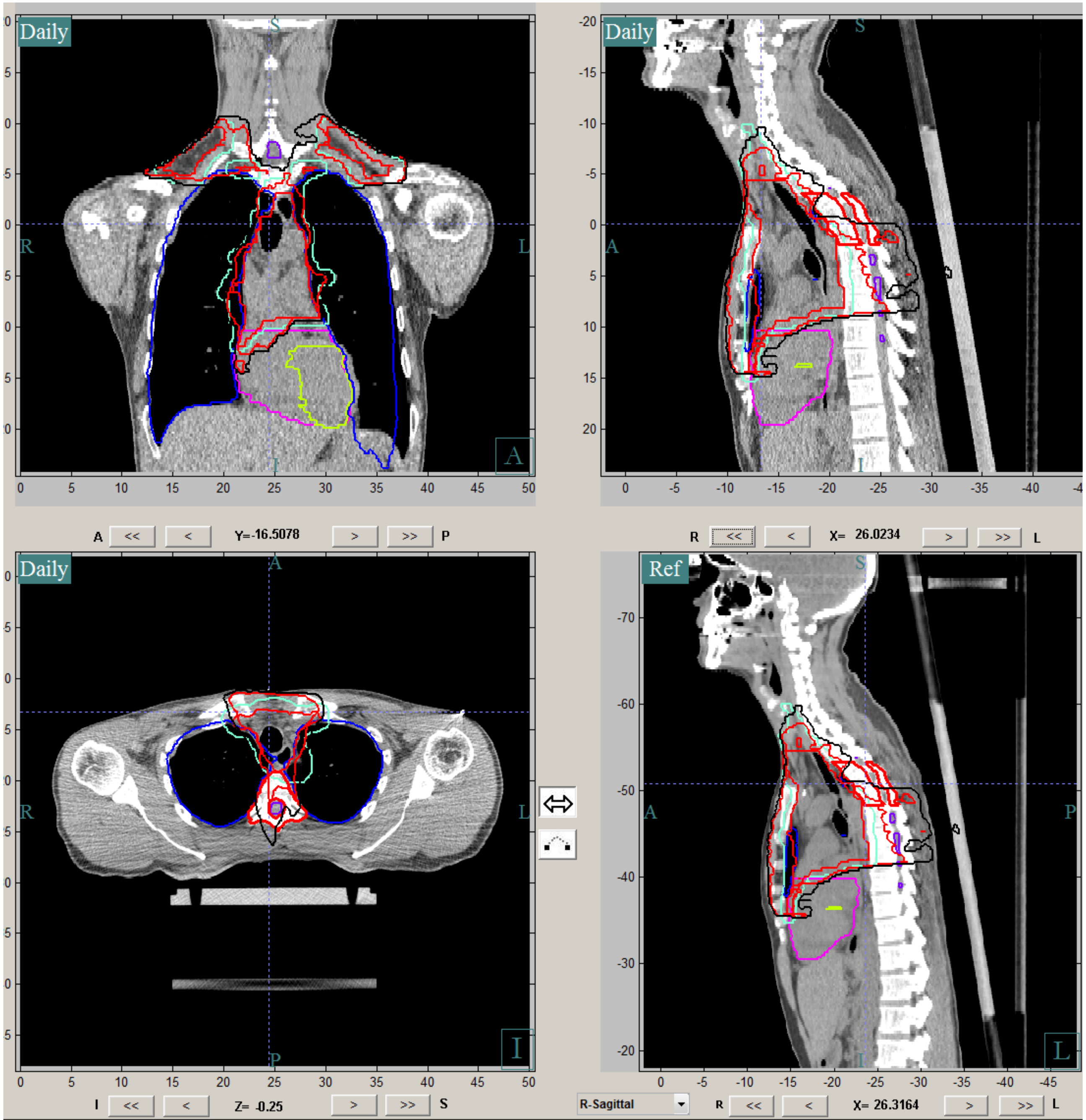
Bucci

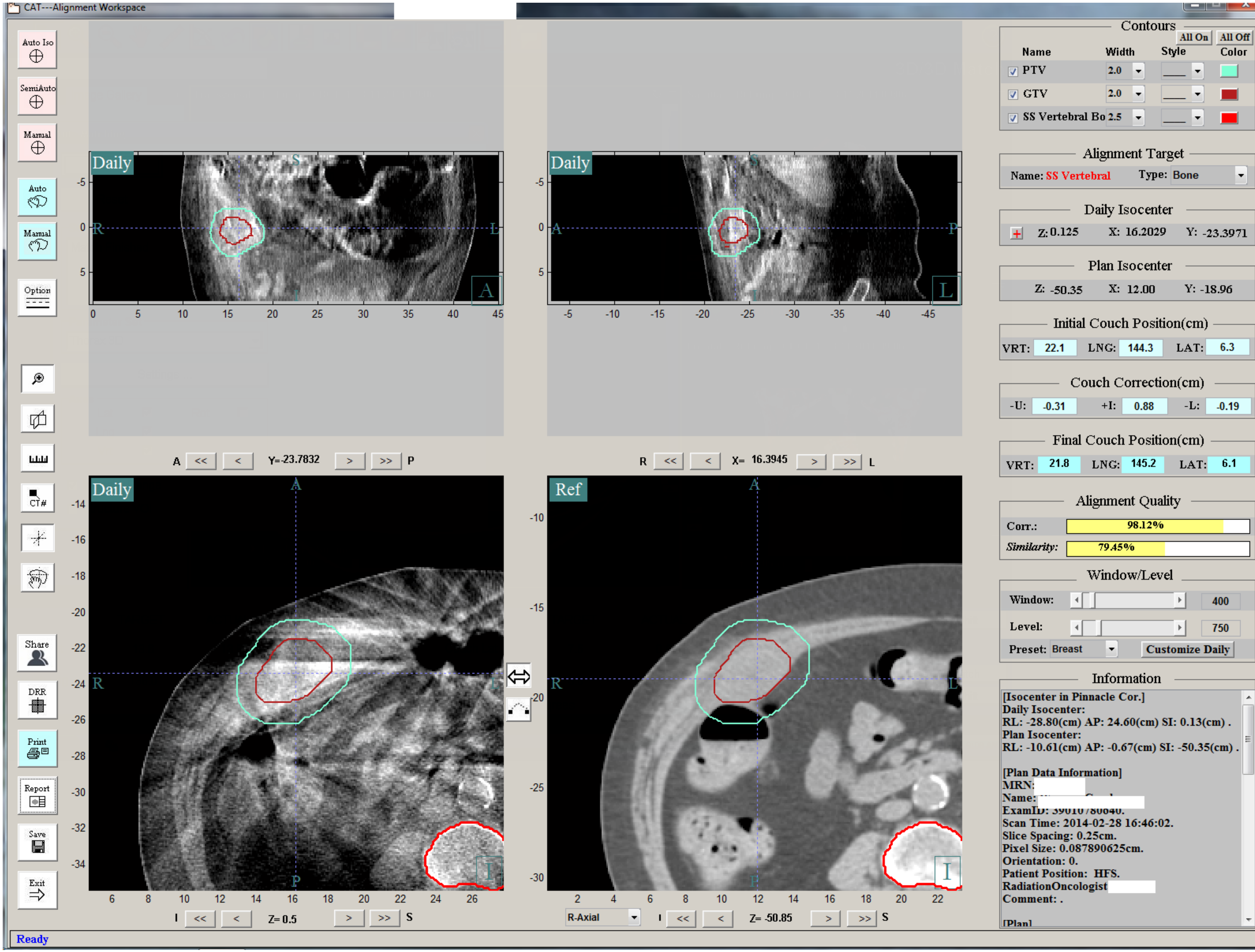
In-room CT: CT-on Rails

- CT-on-rails
  - Diagnostic CT gantry
  - CT is modified to move the CT gantry rather than the patient.
  - Provides a diagnostic quality CT in treatment position
  - Ideal for low contrast (liver) tumors
  - Ideal for long tumors and/or breathhold

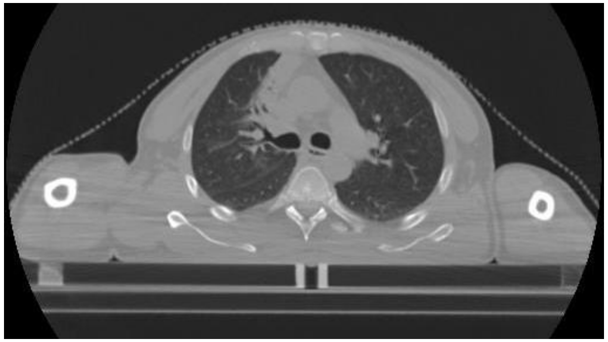



Daily
Daily
A << < Y=-20.4141 > >> P
R << < X= 32.664 > >> L
Daily
Ref
I << < Z= -0.25 > >> S
R-Axial
I << < Z= -16.5 > >> S


Daily
Daily
Daily
Ref
A
Y=-16.5078
P
R
X= 26.0234
L
I
Z= -0.25
S
R-Sagittal
R
X= 26.3164
L


CAT---Alignment Workspace
Auto Iso
SemiAuto
Manual
Auto
Manual
Option
CT#
Share
DRR
Print
Report
Save
Exit
Daily
Daily
Daily
Ref
A << < Y=-23.7832 > >> P
R << < X= 16.3945 > >> L
I << < Z= 0.5 > >> S
R-Axial
I << < Z= -50.85 > >> S
Contours
All On
All Off
Name Width Style Color
PTV 2.0
GTV 2.0
SS Vertebral Bo 2.5
Alignment Target
Name: SS Vertebral Type: Bone
Daily Isocenter
Z: 0.125 X: 16.2029 Y: -23.3971
Plan Isocenter
Z: -50.35 X: 12.00 Y: -18.96
Initial Couch Position(cm)
VRT: 22.1 LNG: 144.3 LAT: 6.3
Couch Correction(cm)
-U: -0.31 +I: 0.88 -L: -0.19
Final Couch Position(cm)
VRT: 21.8 LNG: 145.2 LAT: 6.1
Alignment Quality
Corr.: 98.12%
Similarity: 79.45%
Window/Level
Window: 400
Level: 750
Preset: Breast
Customize Daily
Information
[Isocenter in Pinnacle Cor.]
Daily Isocenter:
RL: -28.80(cm) AP: 24.60(cm) SI: 0.13(cm) .
Plan Isocenter:
RL: -10.61(cm) AP: -0.67(cm) SI: -50.35(cm) .
[Plan Data Information]
MRN:
Name:
Scan Time: 2014-02-28 16:46:02.
Slice Spacing: 0.25cm.
Pixel Size: 0.087890625cm.
Orientation: 0.
Patient Position: HFS.
RadiationOncologist
Comment: .
Ready

CT-on-rails vs. Cone Beam



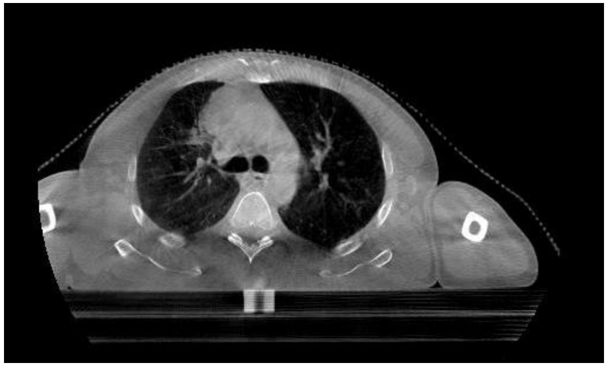
< 5 min acquisition and reconstruction time

Patient is rotated into scanning position on treatment couch (lateral and vertical shifts required)

Isocenter not linked to images

Each slice is a 0.5 sec time average

50 cm FOV (full scan)



< 5 min acquisition and reconstruction time

Patient is imaged in treatment position (except for lateral shifts)

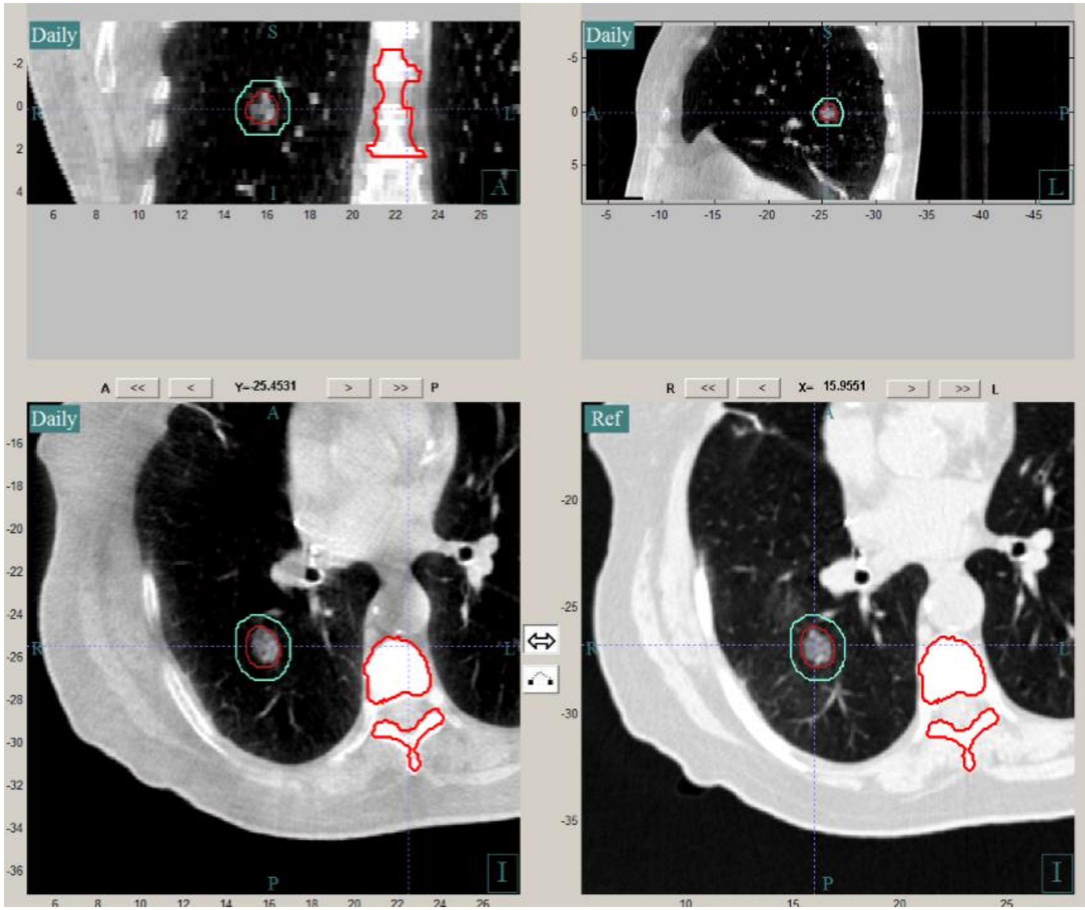
Isocenter defined in CT space

Each slice is a 60 sec time average

45 cm FOV half-scan

Breath-hold CBCT to improve image quality

- Some of the poor quality in current generation CBCT in the lung is due to breathing motion
- BH-CBCT can be used when performing SBRT on low contrast tumors or small tumors with large motion ranges



Localization of Images in space

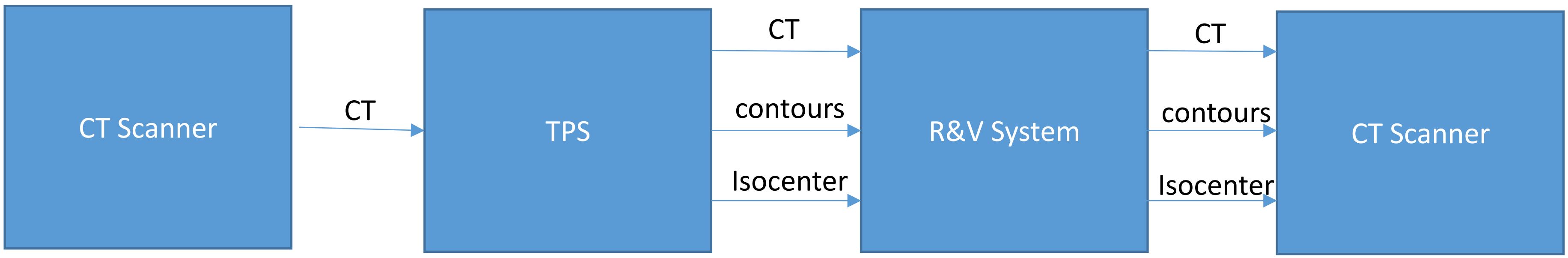
- Current radiotherapy systems use DICOM-RT to define the location of images, isocenters, contours with respect to each other.
- Each radiotherapy plan has a “primary image set” that is used to define the coordinate system for all other objects
- Other image sets can be used to assist in contouring
  - If these sets are from the imaging session they may share the DICOM coordinate set

Data flow

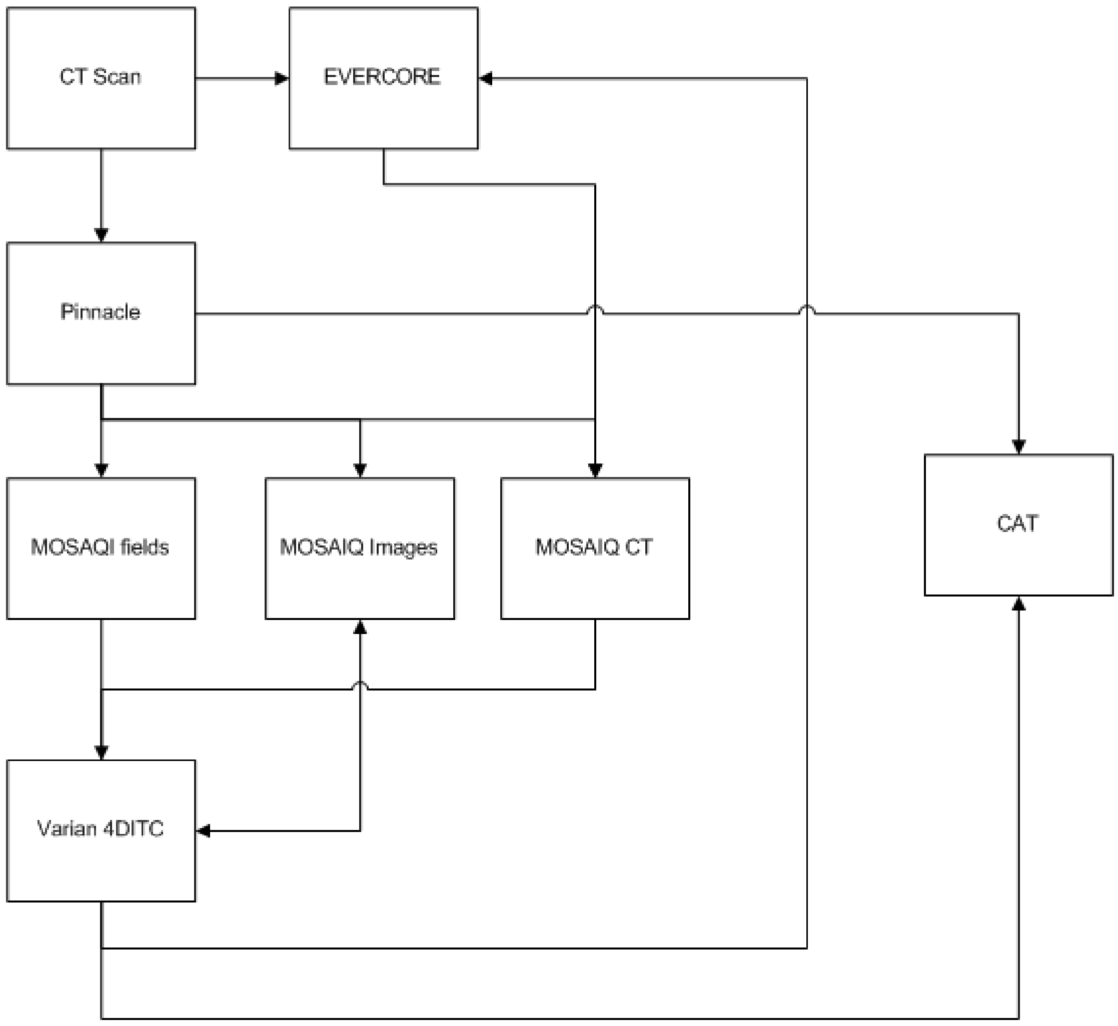
- The reference CT for CT-CT matching needs to be chosen and communicated to the treatment console
- The reference structures as well
- The isocenter co-ordinates

Verification of all of these should be part of pre-treatment physics QA (Plan-Check)

Example data-flow in Pinnacle-MOSAIQ-Varian environment



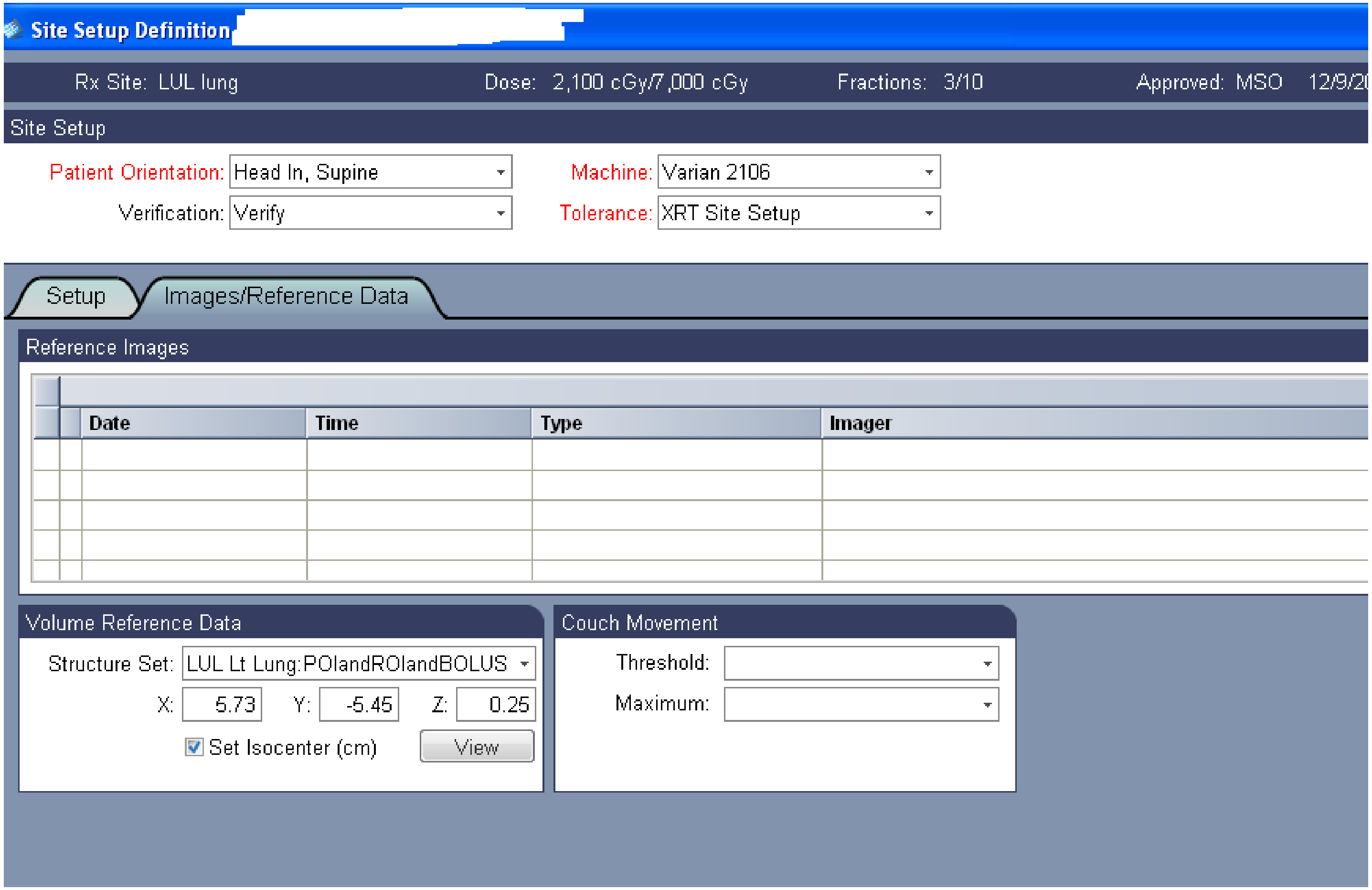
Data Flow For IGRT at MDACC



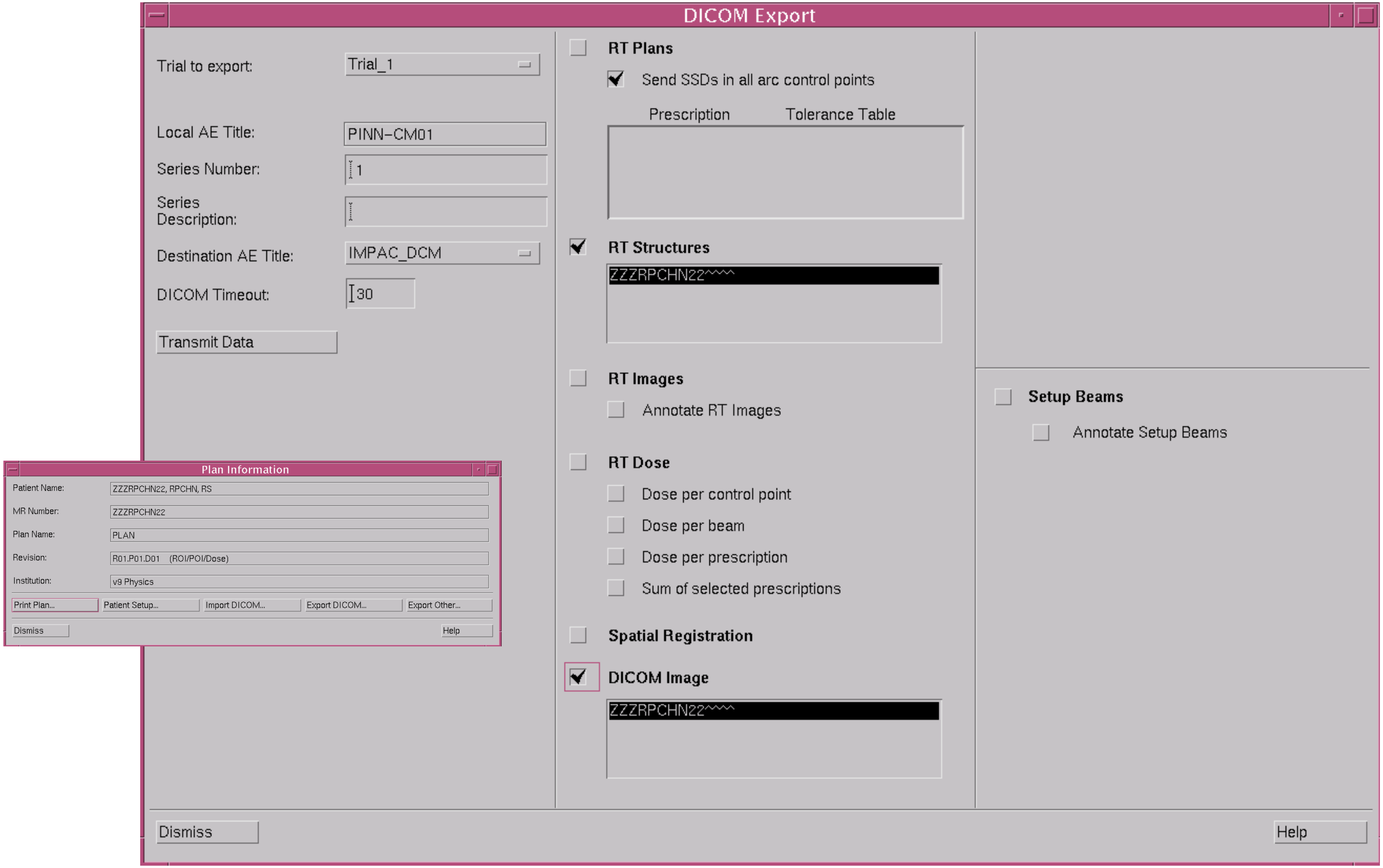
Note: CAT is in-house 3D-3D match system

Localization of images in Space

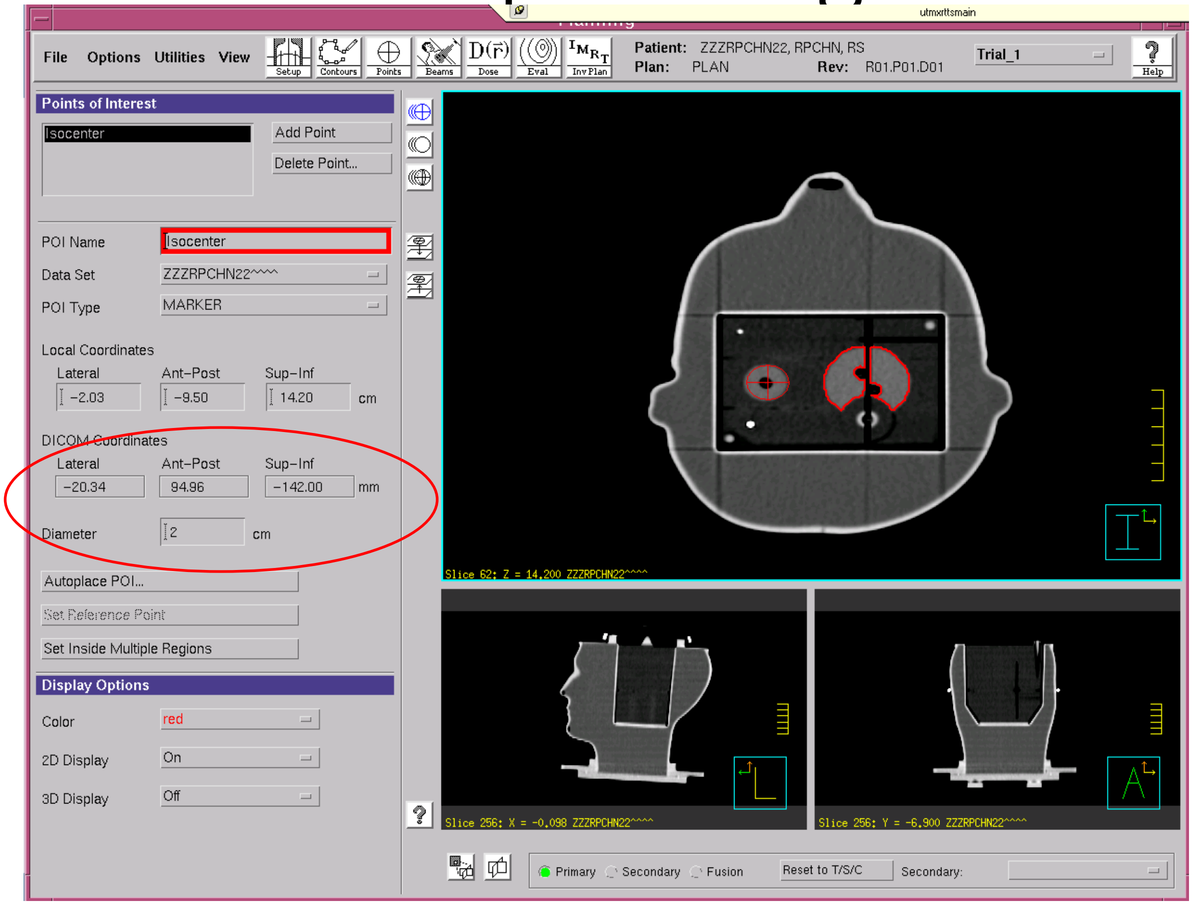
- The CT is related to the treatment site via UID in the RT structure set
- The localization of the CT to the isocenter is contained in 3 numbers that are easy to get wrong
- CT setup should always be verified against some other system on the first day of treatment (we use MV ports are verification on our SBRT cases)



TPS DICOM export should send needed values to R&V system



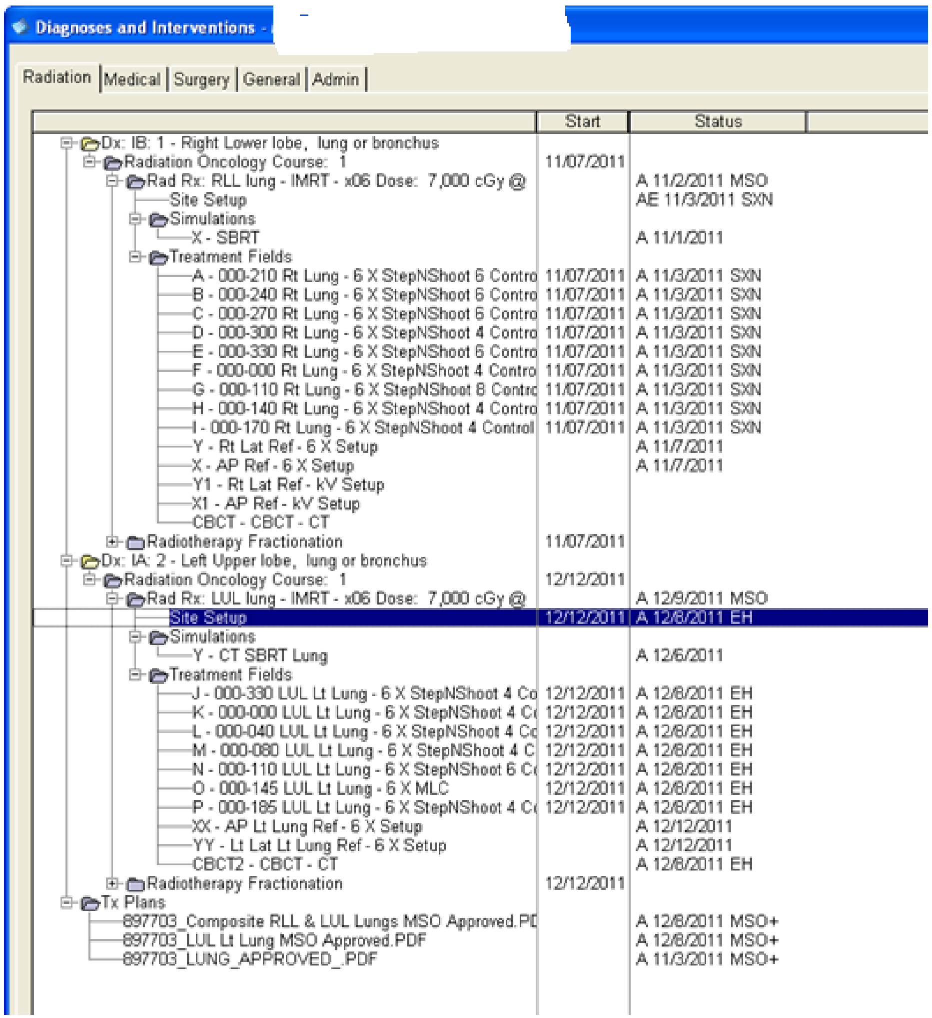
CT coordinates can be looked up in the POI section of the planning window



Plan checks in the IGRT world should (shall ?) include checking isocenter coordinates and reference data set.

Localization of images in Space

- For patients with multiple isocenters there is more opportunity for error



Choice of Reference CT dataset

- If only 1 planning CT dataset – easy no choice
- If 4DCT
  - We use Average intensity projection since CBCT is nearly equivalent to an average CT due to the slow acquisition (1 breath cycle per 20 deg arc)
  - Mid-ventilation would be reasonable
  - MIP is good to provide contours but should not be used for planning or reference
- If breath-hold or gating
  - Should be reference image taken from BH or the central phase of the gating window

Clinical applications and Limitations of CT localization

Applications

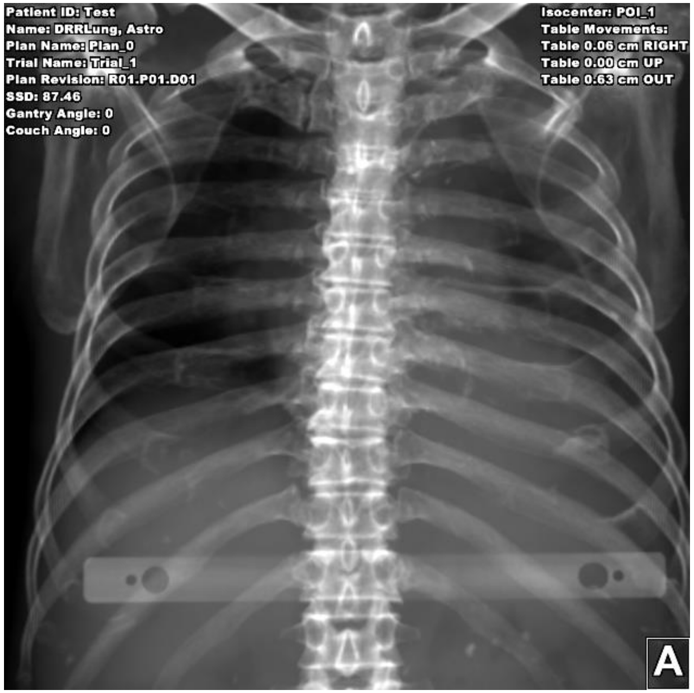
- IGRT
  - Reduced margins
  - Soft tissue targeting
  - Verification of setup surrogates
  - Verification of anatomy vs plan
- SBRT
- Gating
- Adaptive planning
  - Dose calc on CBCT
  - Triggered re-sims

Limitations

- Low contrast objects
- Multiple targets
- Changing targets
- Dose vs Structures for setup

In-room CT use case: Verification of Daily Projection Imaging

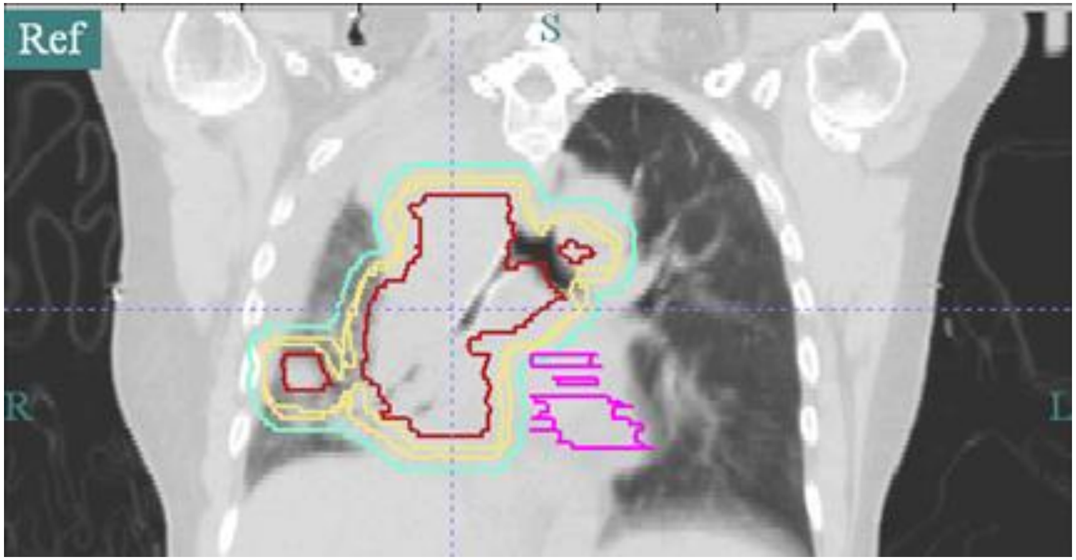
- CBCT can be used to test the appropriateness of projection imaging for daily setup



- MDACC Protocol:
  - Daily orthogonal pair kVp Images
  - Weekly CBCT (setup to bone) to validate:
    - The use of kVP for daily
    - The appropriateness of the plan for the changing anatomy
  - Other protocols
    - Daily CBCT
    - CBCT for several days to create patient specific margins

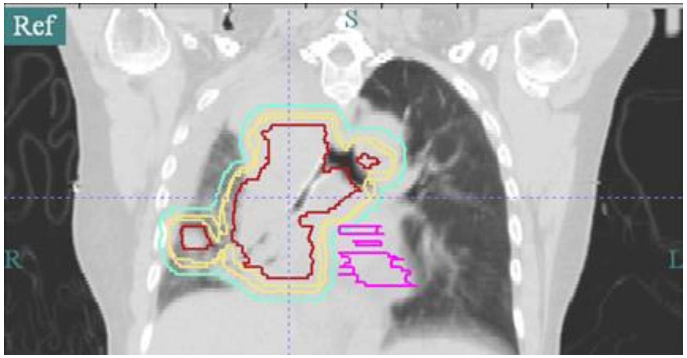
Monitoring of patient during the course of treatment

- Tumors can change during 6 weeks of radiotherapy
- This can cause the target to move outside of the target when the patient is aligned on bones (daily kVp imaging)

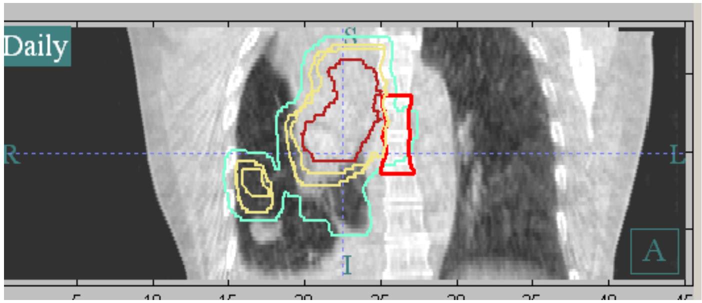


Rapidly Changing Patient: Comparison between CBCT and projection Imaging

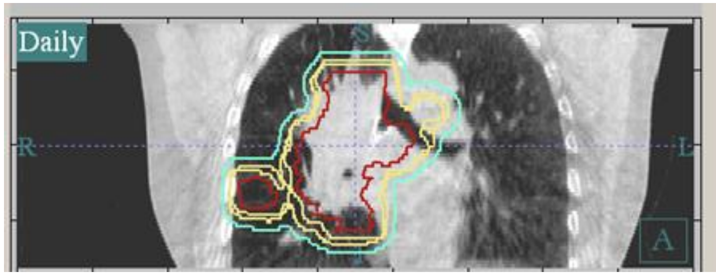
Simulation



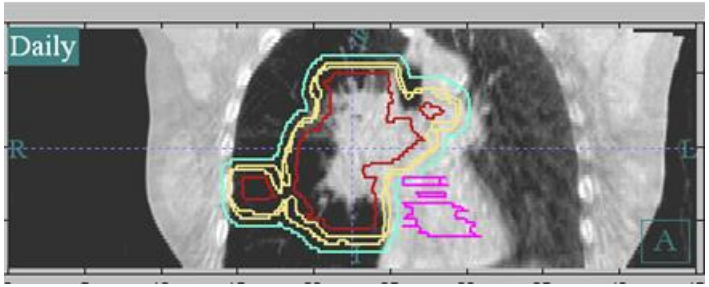
Treatment Day 1



Day 5

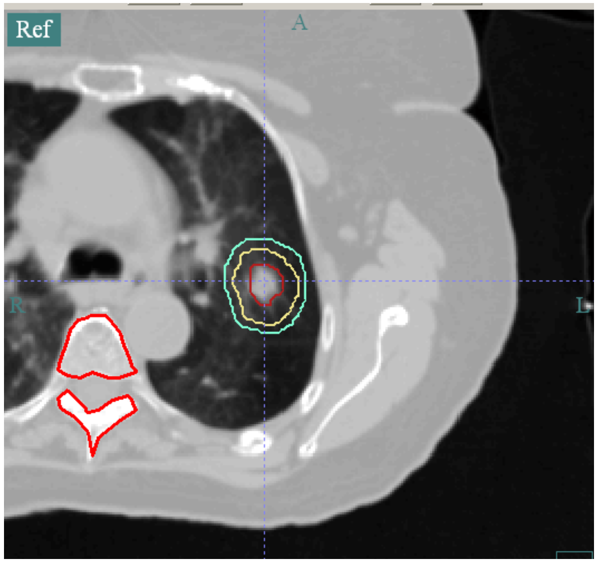


Day 10

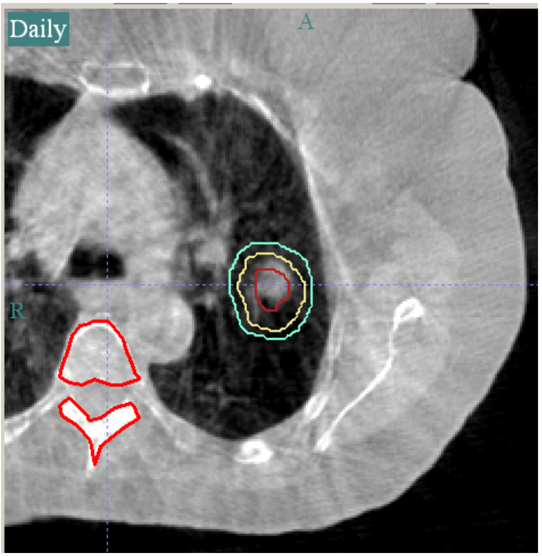


10/11/2010

CBCT to adapt to daily anatomy changes



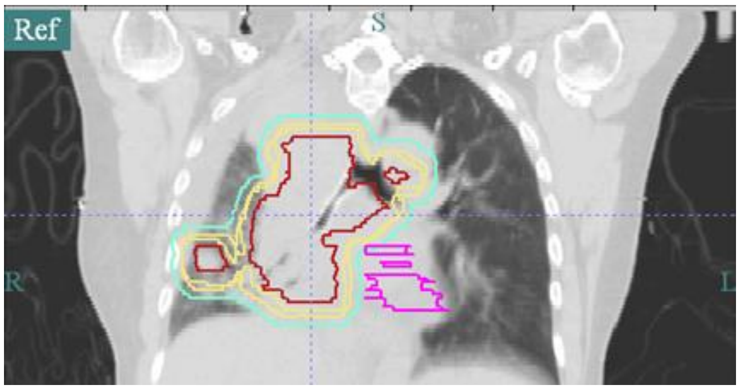
Planning CT



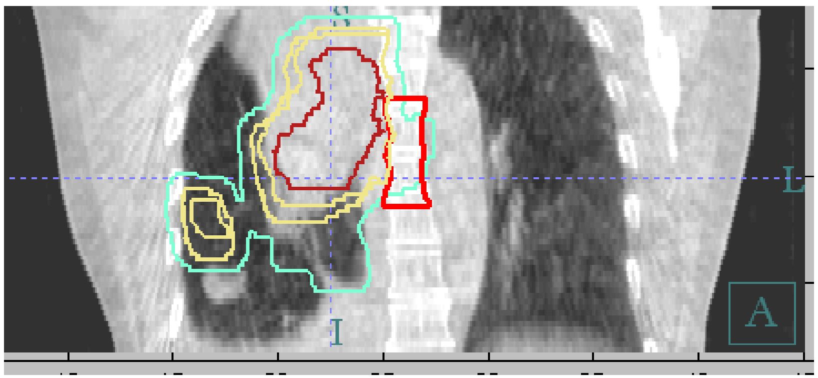
CBCT

- CBCT can be used to adapt plan by shifting isocenter to cover target
- SBRT in lung is an ideal use-case
  - Targets don’t change in a few fractions
  - High contrast between lung and GTV
  - CBCT slow acquisition can be an asset (averages tumor motion)

CBCT used to trigger a new planning CT



Planning CT



CBCT

- Obvious Geometric Miss
- Shifting Isocenter cannot restore coverage
- CBCT doesn't have enough range or quality to adequately replan

Re-planning (adaptive)

- Dose can be re-calced on Daily CT
  - CT-on-rails/Tomotherapy: Direct dose recalculation
  - CBCT
    - HU values can be calibrated: Megavoltage Photons are not particularly sensitive to HU accuracy
    - Length and/or FOV is more of a limitation
    - Poor quality for re-contouring
      - Abdomen – poor contrast

Radiotherapy and Oncology 85 (2007) 116–125
www.thegreenjournal.com

A study on adaptive IMRT treatment planning using kV cone-beam CT

George X. Ding*, Dennis M. Duggan, Charles W. Coffey, Matthew Deeley, Dennis E. Hallahan, Anthony Cmelak, Arnold Malcolm

Department of Radiation Oncology, Vanderbilt University, Nashville, TN, USA

A study on adaptive IMRT treatment planning using kV cone-beam CT

George X. Ding*, Dennis M. Duggan, Charles W. Coffey, Matthew Deeley, Dennis E. Hallahan, Anthony Cmelak, Arnold Malcolm

Department of Radiation Oncology, Vanderbilt University, Nashville, TN, USA

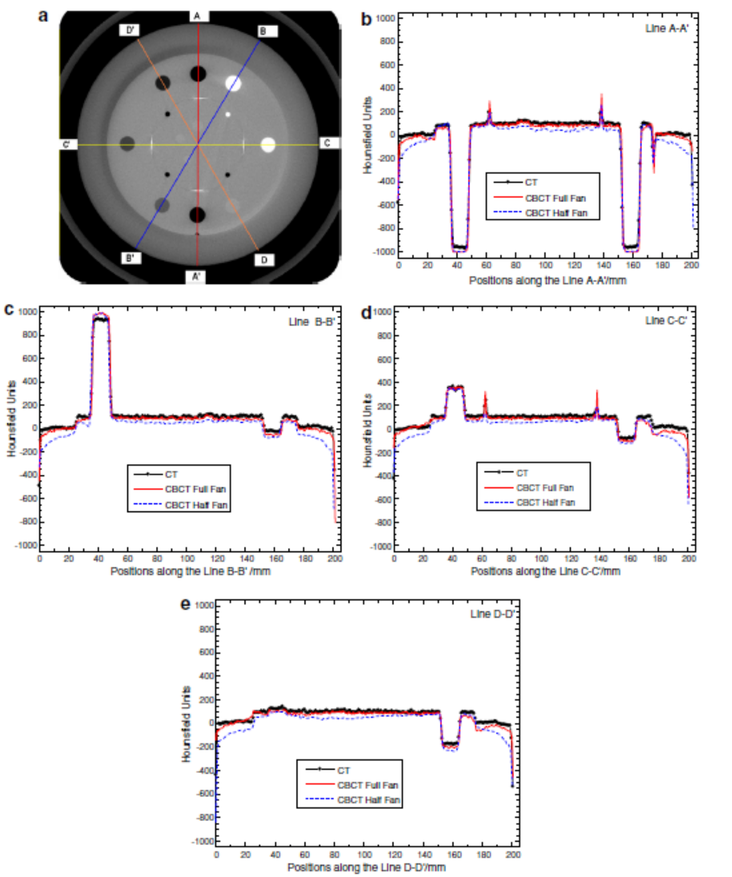


Fig. 2. A CBCT image slice of Catphan phantom containing high and low density materials and four lines (a) and the comparison of Hounsfield Units determined between conventional CT and CBCT along these four different lines (b–e). The diameter of Catphan phantom is 200 mm.

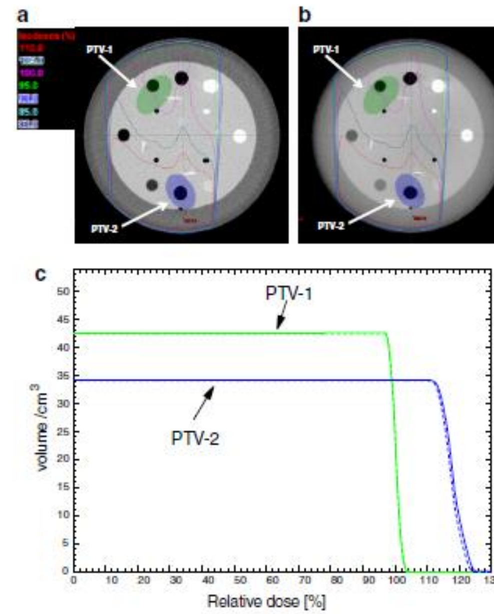


Fig. 3. Calculated dose distributions in an inhomogeneous phantom (CatPhan 600) shown on a CT slice (A) from a Picker 500 scanner and on a CBCT slice (B) from a Trilogy OBI. Two target volumes, PTV-1 shown in green and PTV-2 shown in blue, were contoured on the CT images and then copied to the CBCT images. Calculated dose–volume histograms using CT and CBCT images for target volumes PTV-1 and PTV-2 are shown in (C). The solid and dash lines are for CT and CBCT respectively.

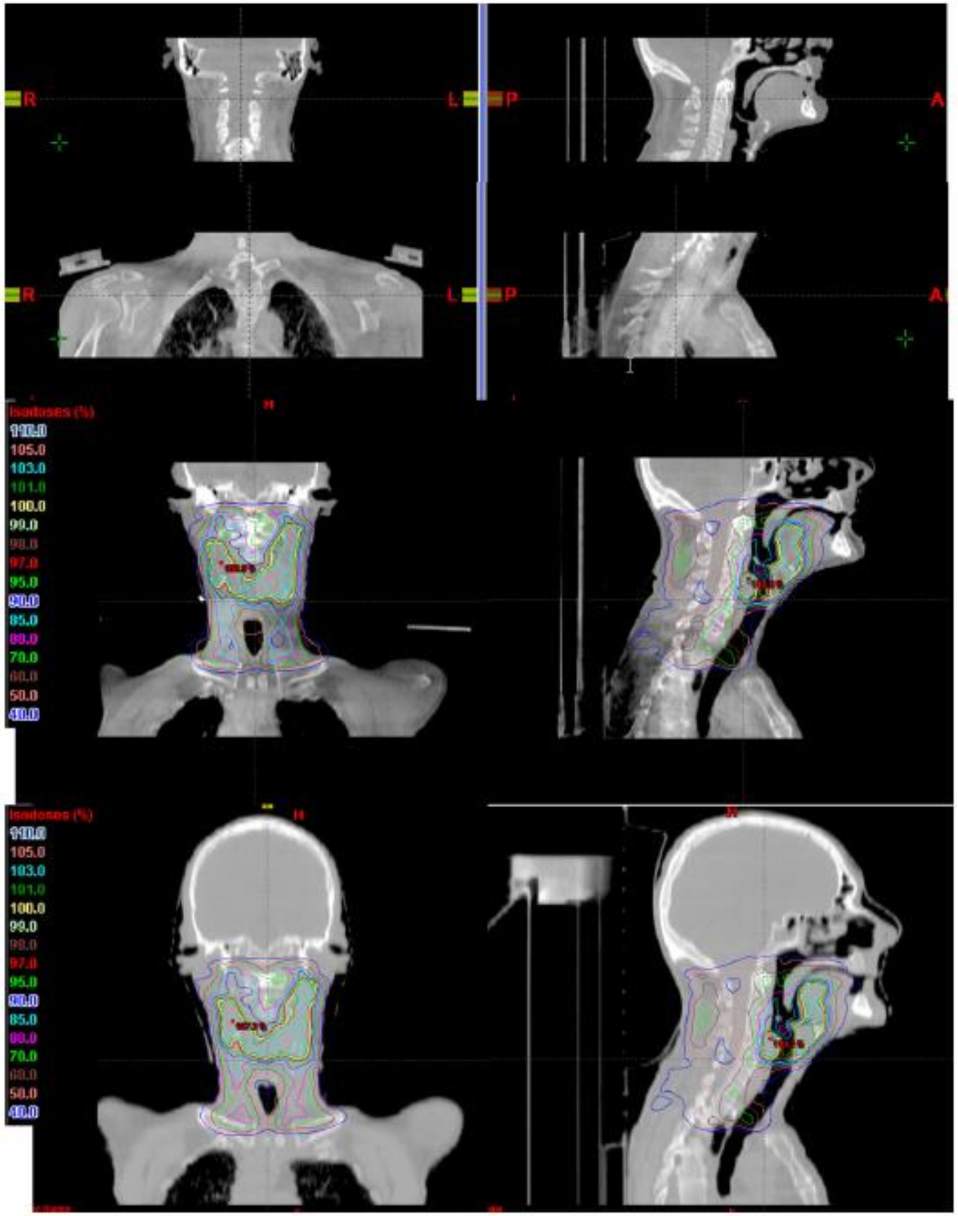
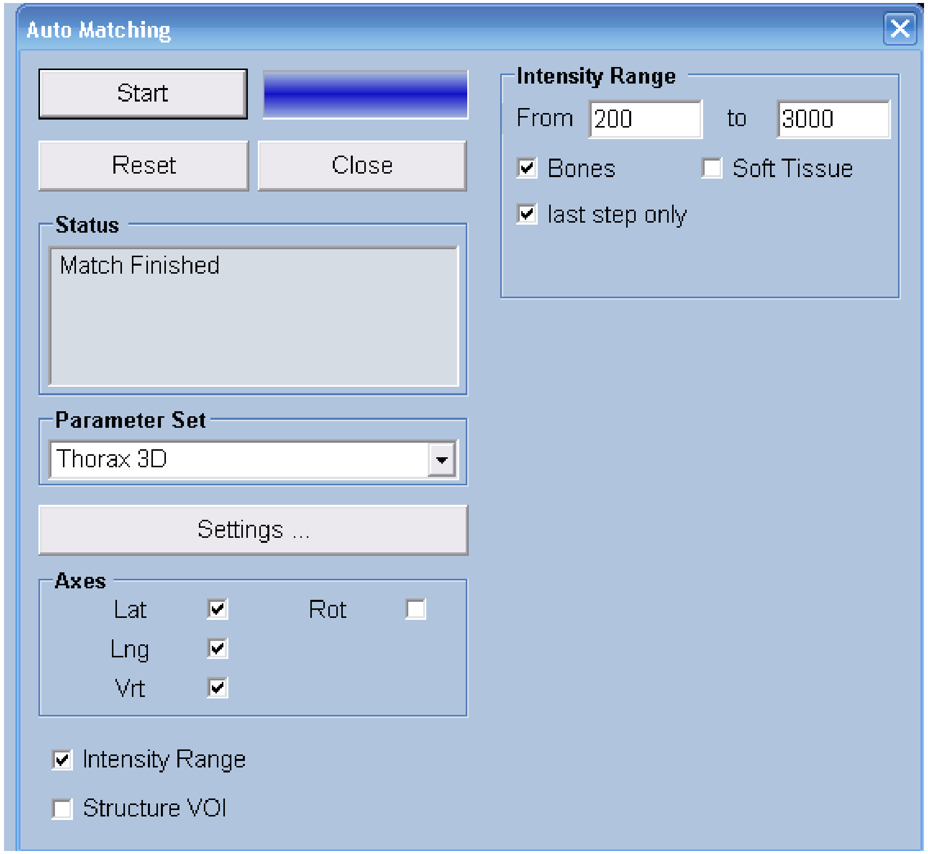


Fig. 4. Two 14 cm long CBCT acquisitions (upper) were combined into one head and neck CBCT volumetric image (middle) for dosimetric comparison between using CBCT and CT image (lower) in IMRT treatment planning.

Registration of Daily CT to Planning CT

- Algorithm
  - Varian – Mutual Information
  - Elekta
    - Soft tissue: Cross correlation
    - Bone: Chamfer matching
- Region-of-Interest
  - Clip Box
  - Structure from planning
  - HU value ranges
  - Combination of the above



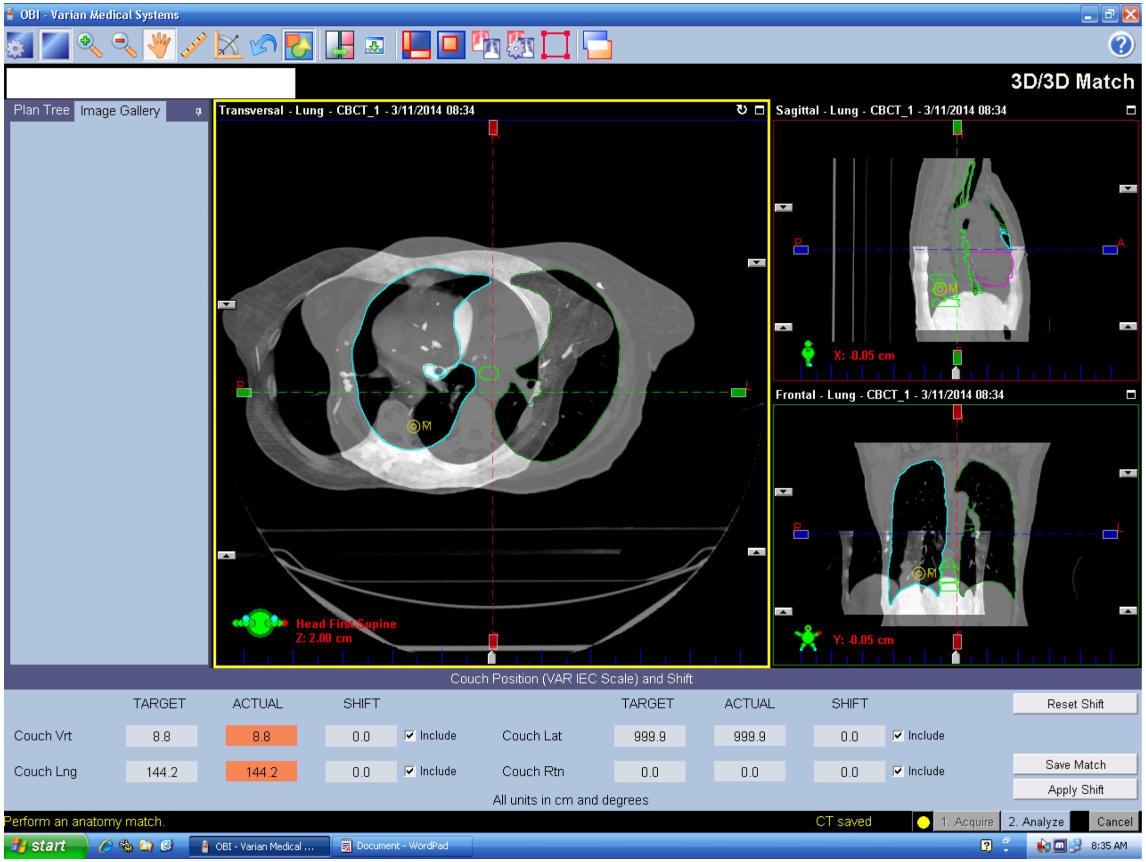
A combination of manual and automatic tools will give the best results

Example:

Scanned with couch at zero

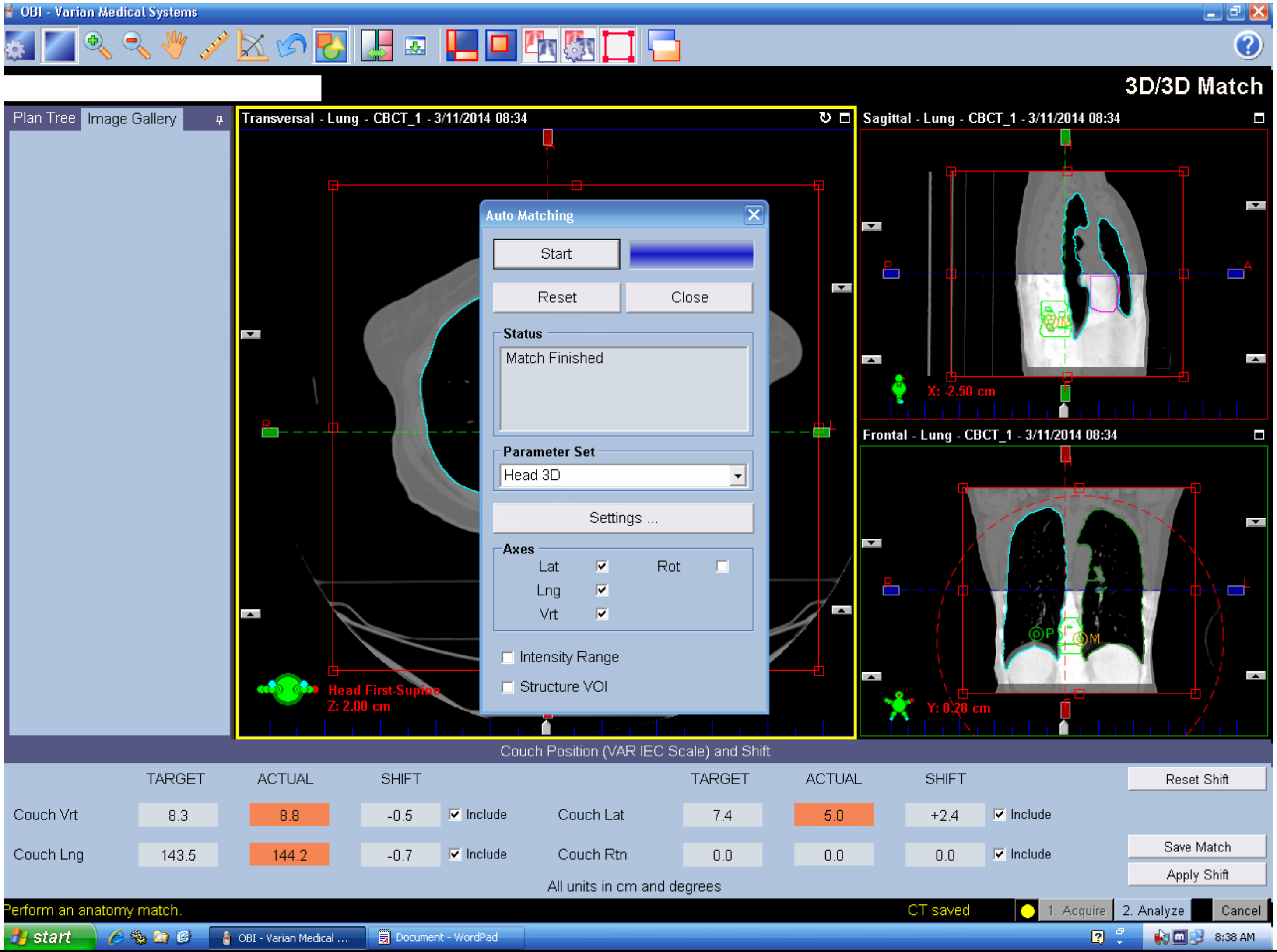
Manual shift should be done prior to auto-match

Manual fine-tuning if often done after auto-match

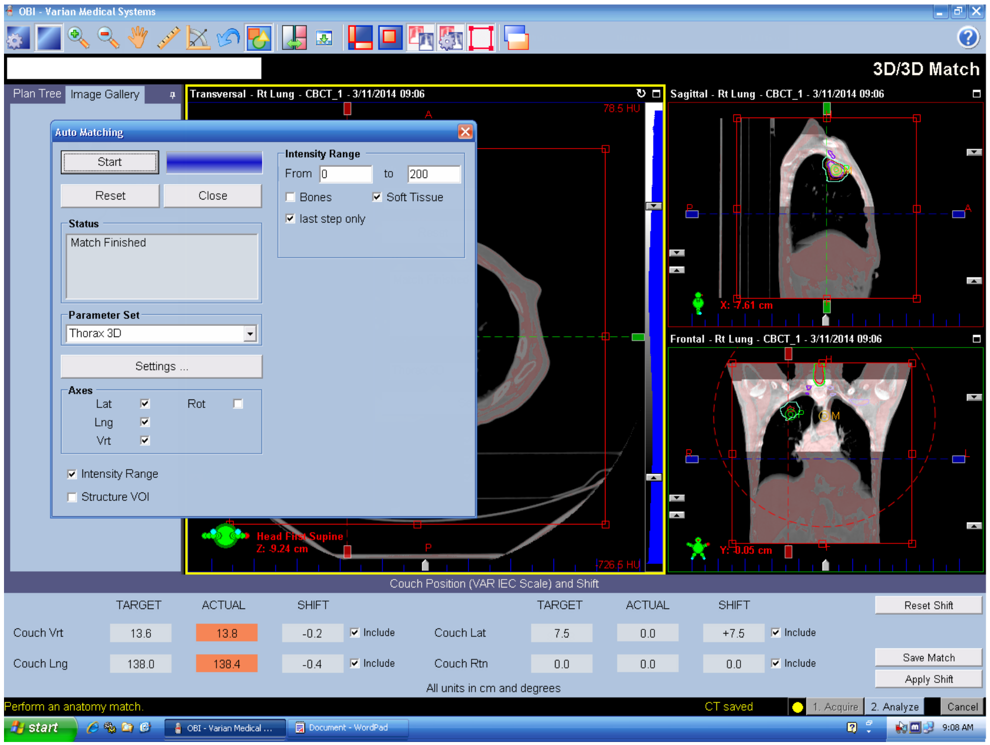


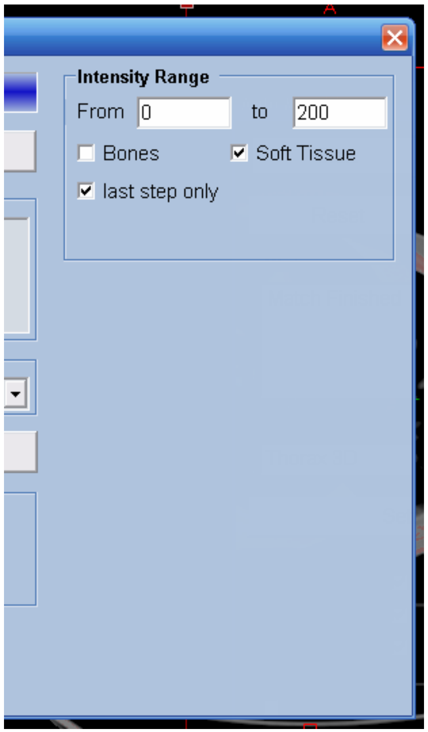
Note: we often leave the couch at lateral zero when we do CBCT to avoid a) an extra step for the therapist b) an error between MOSAIQ and VARIAN in SRO processing

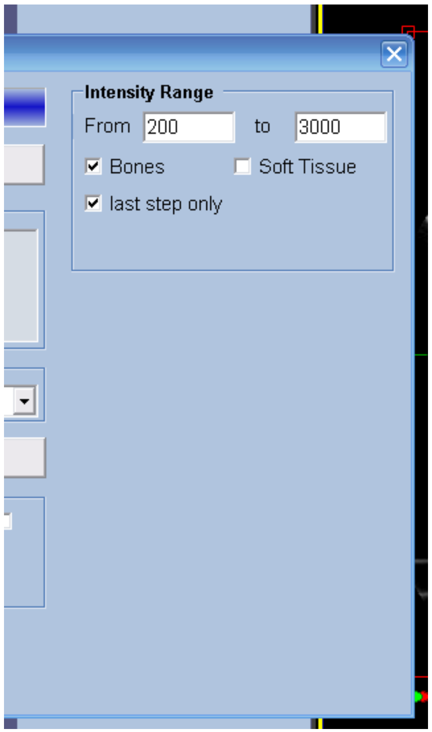
Automatic tools should be chosen for each patient (not just the default)



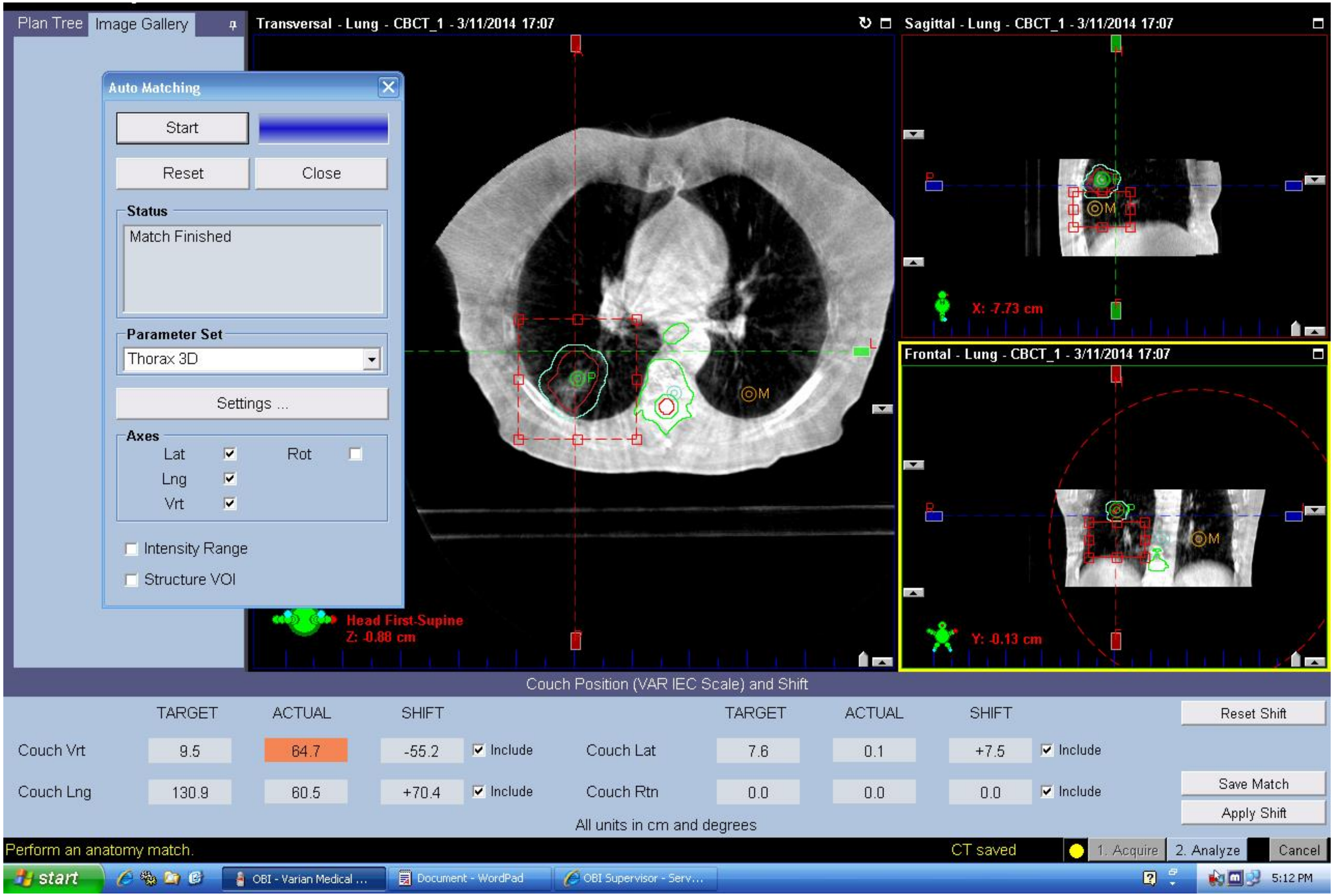
Auto match can be restricted to an HU value range to emphasize different materials.



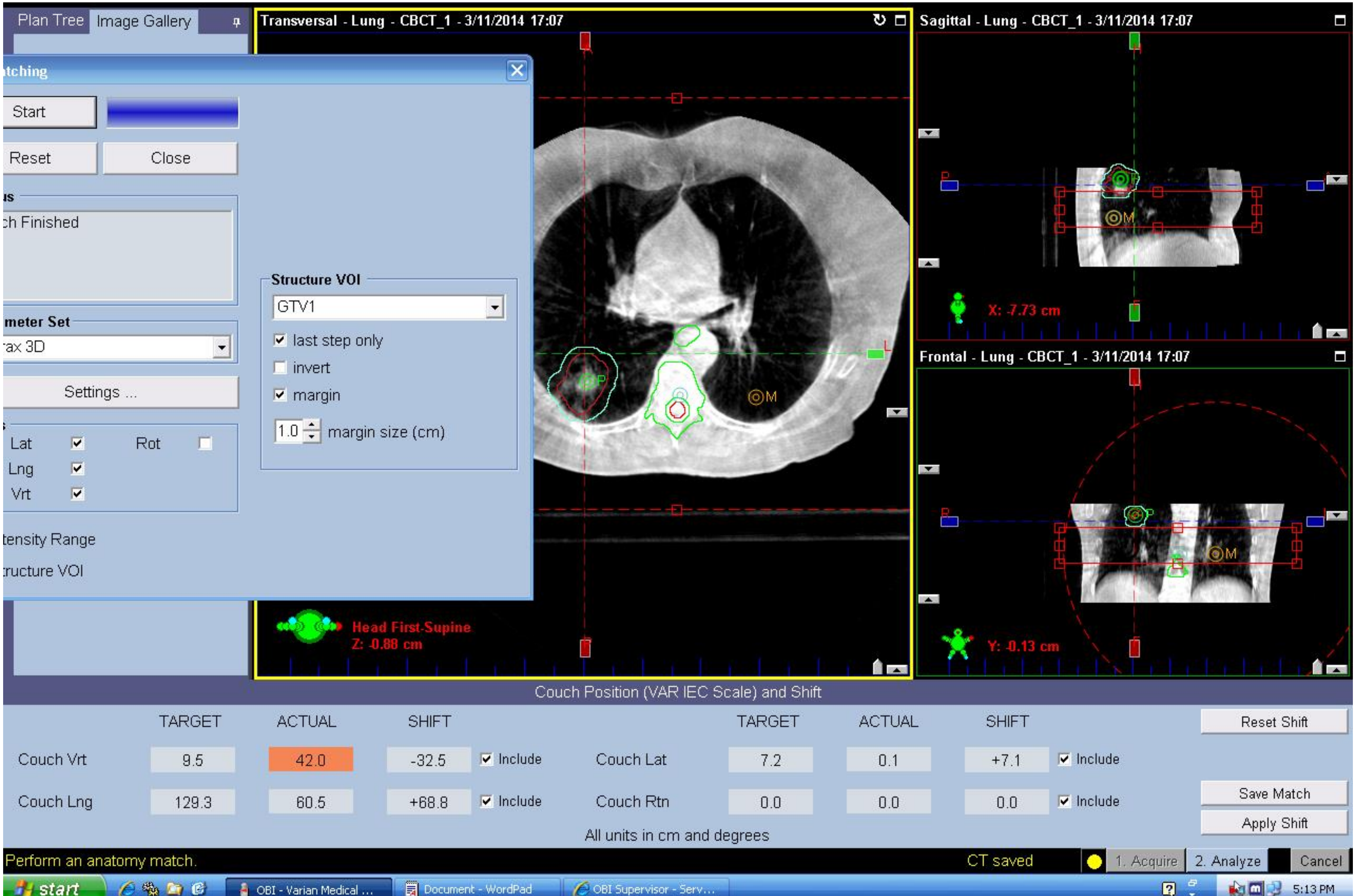




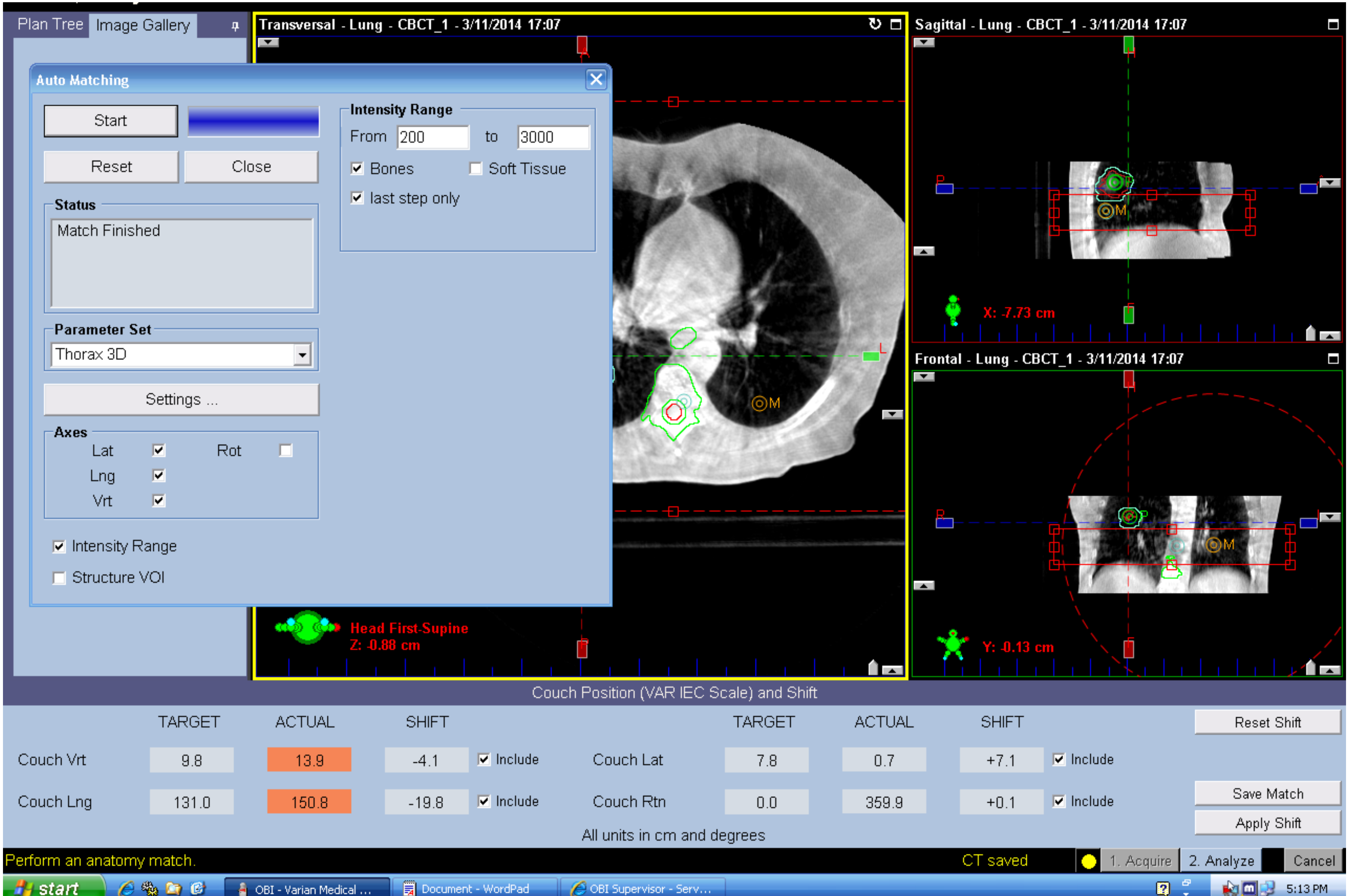
Auto match can be restricted to a geographical region (clipbox)



The best way to define a region for matching is by using an ROI

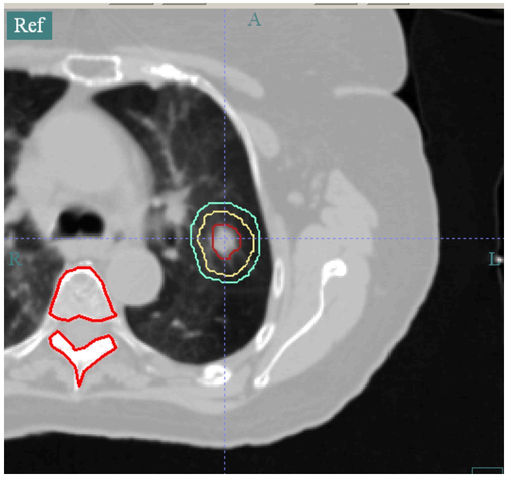


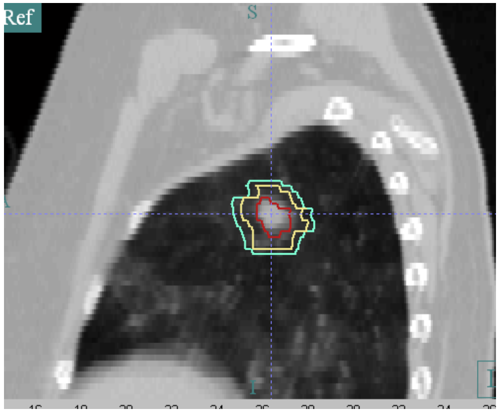
These tools can be combined



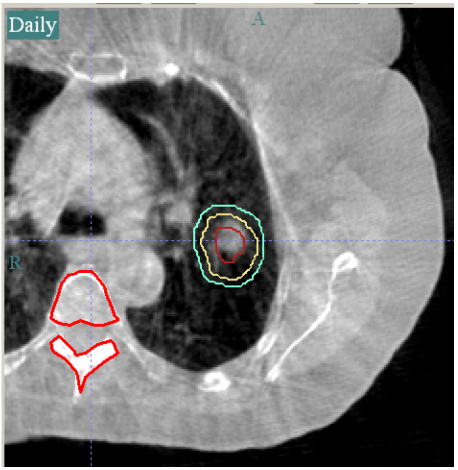
Choice of Surrogate

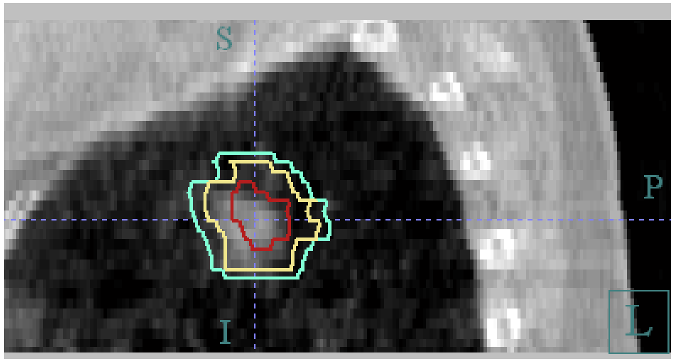
Simulation





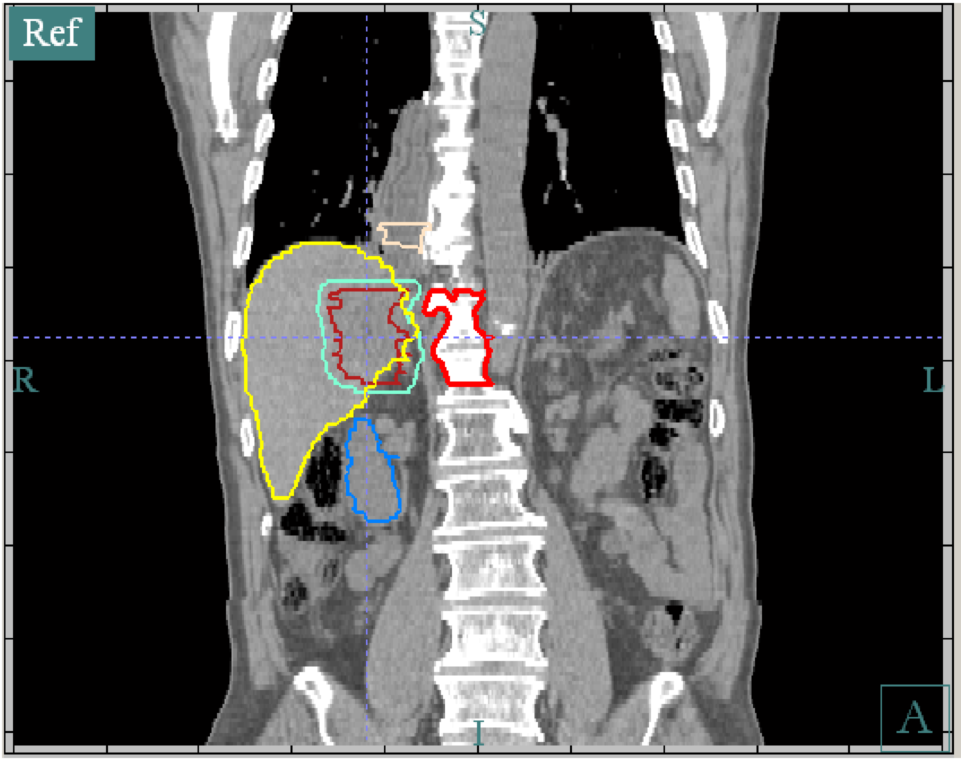
Treatment



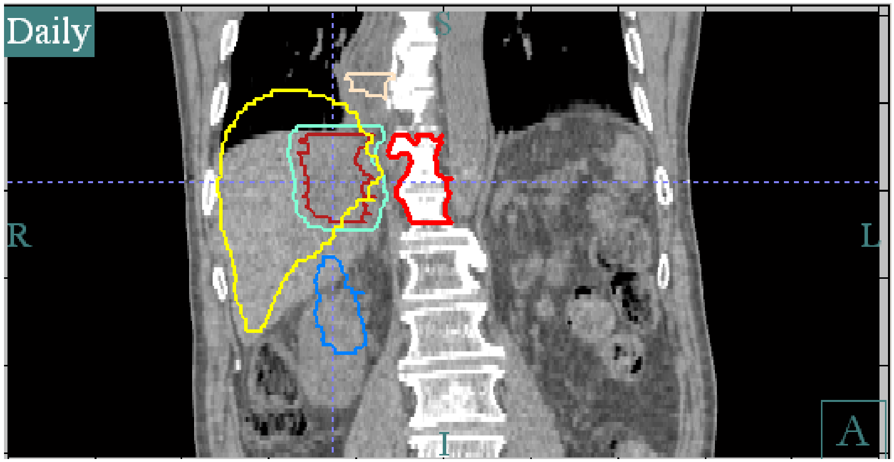


If boney anatomy were used as a surrogate a larger PTV would be needed to cover the target

Difference between bone and soft tissue

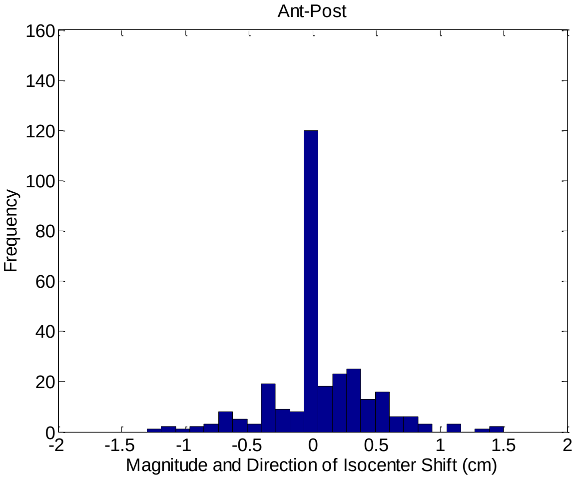


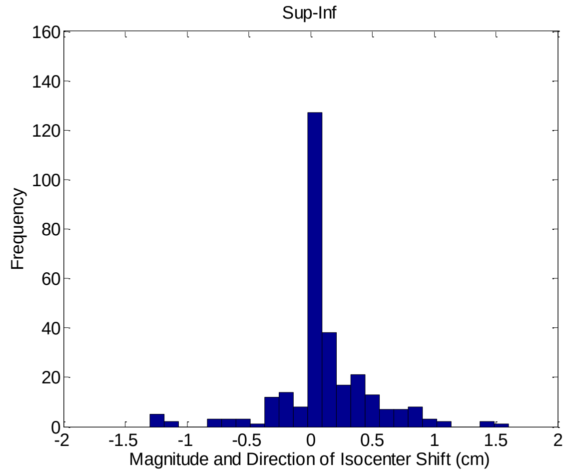
Planning CT

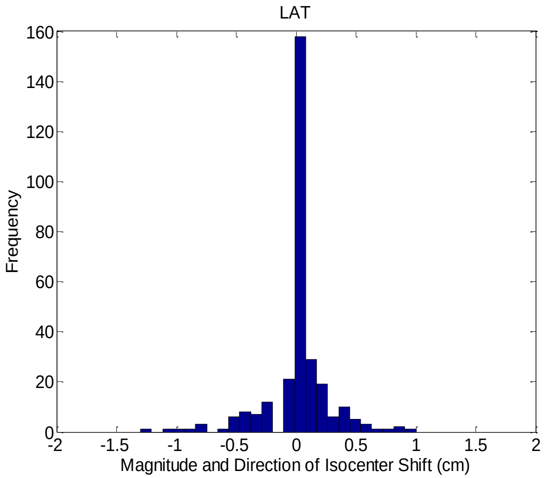


In room CT-on-Rails

Differences between Boney Anatomy Based Setup and Soft tissue (GTV) based setup







76 Lung SBRT patients treated at MDACC
Average differences: 0.1 ± 0.4 cm in anterior-posterior (AP)
0.1 ± 0.4 cm in superior-inferior (SI)
0.0 ± 0.3 cm
Maximum observed 1.5 cm in AP direction
1.6 cm in SI
1.3 cm laterally

ARTICLE IN PRESS

Practical Radiation Oncology (2012) **xx**, xxx–xxx

pro
www.practicalradonc.org

Review Article

Evaluation of dose variation to normal and critical structures for lung hypofractionated stereotactic body radiation therapy

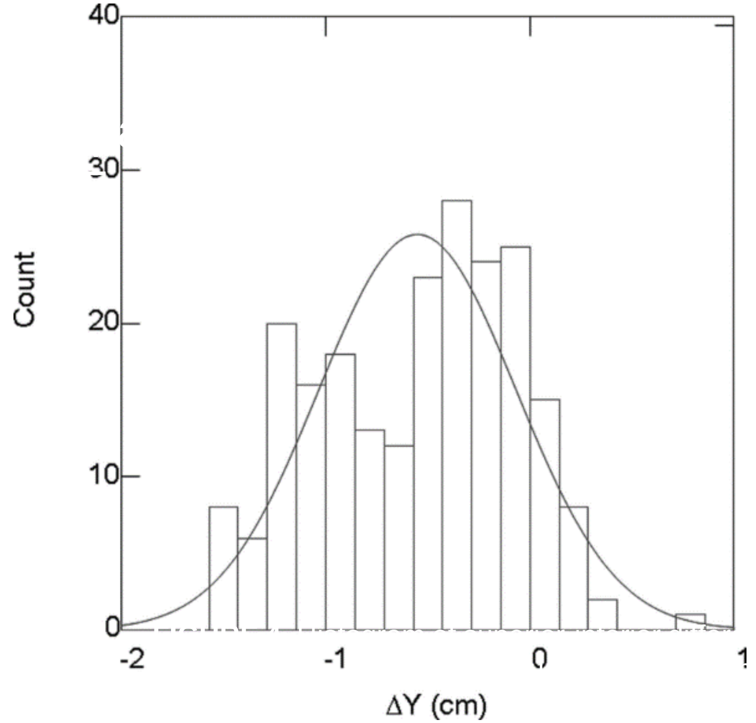
Heeteak Chung PhD[a,*], Laurence Court PhD[a], Steven H. Lin MD, PhD[b], Dhananjay Kulkarni MBBA[c], Peter Balter PhD[a]

[a]*The University of Texas MD Anderson Cancer Center, Department of Radiation Physics, Houston, Texas*
[b]*The University of Texas MD Anderson Cancer Center, Department of Radiation Oncology, Houston, Texas*
[c]*The School of Public Health, The University of Texas Houston, School of Medicine, Houston, Texas*

Received 21 September 2011; revised 2 January 2012; accepted 5 January 2012

Auto-registration with 3D imaging NOT accurate

- University of Florida study compared automatic gray value alignment to gold-fiducial marker alignment in 6 patients with and without fiducials



Am J Clin Oncol. 2011 Feb;34(1):16-21.

Remote 3D IGRT Review for RTOG Trials

- Int J Radiat Oncol Biol Phys 2012 Apr 27. [Epub ahead of print]
- Remote review carried out for 87 3D cases
- average differences between reviewers and institutions 2 mm - 3 mm.
- Largest sup-inf for MVCT due low spatial resolution

Table 3 Registration differences between institutions and reviewers (for different imaging modalities)

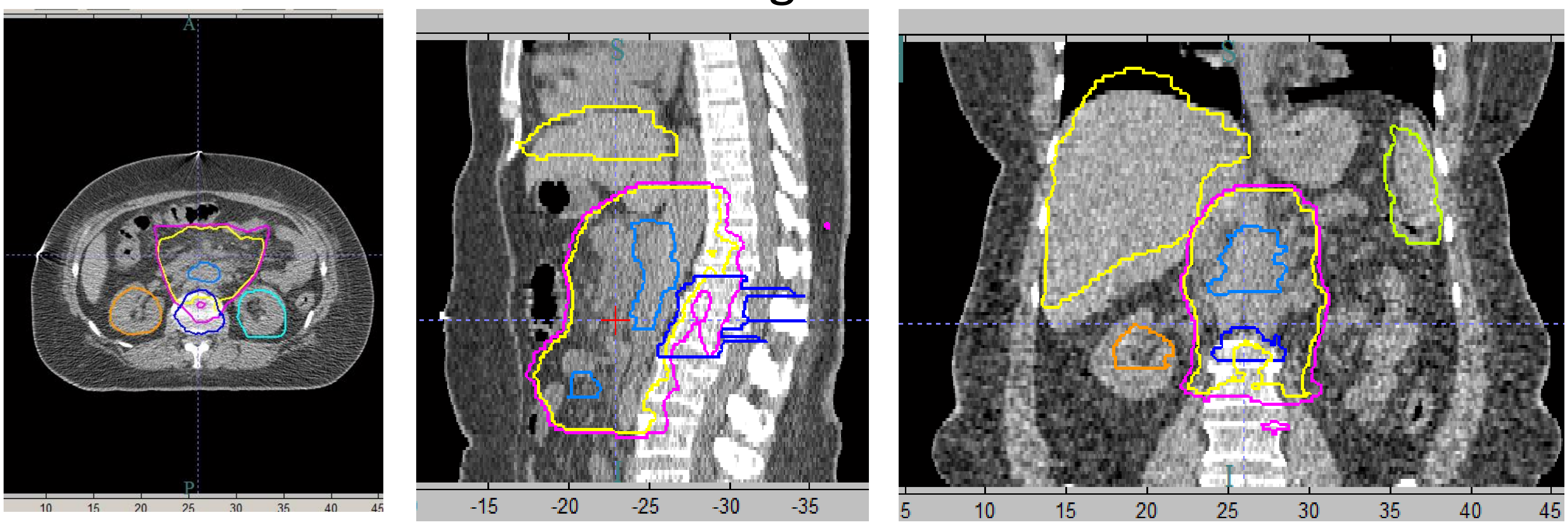
Imaging modality	No. of datasets	Absolute value of difference of shifts (mm), mean ± SD (range)		
		Left-right	Superior-inferior	Anterior-posterior
kV CBCT	96	1.7 ± 1.1 (0.0-6.7)	1.6 ± 0.9 (0.0-6.9)	1.7 ± 1.1 (0.0-5.0)
MVCT	37	1.5 ± 1.0 (0.1-5.1)	3.7 ± 1.7 (0.1-8.2)	1.9 ± 0.9 (0.0-7.3)
Overall	133	1.7 ± 1.0 (0.0-6.7)	2.2 ± 1.5 (0.0-8.2)	1.8 ± 1.0 (0.0-7.3)

Abbreviations: kV = kilovoltage; CBCT = cone-beam CT; MVCT = megavoltage CT.

Bucci

Dose vs structure for setup

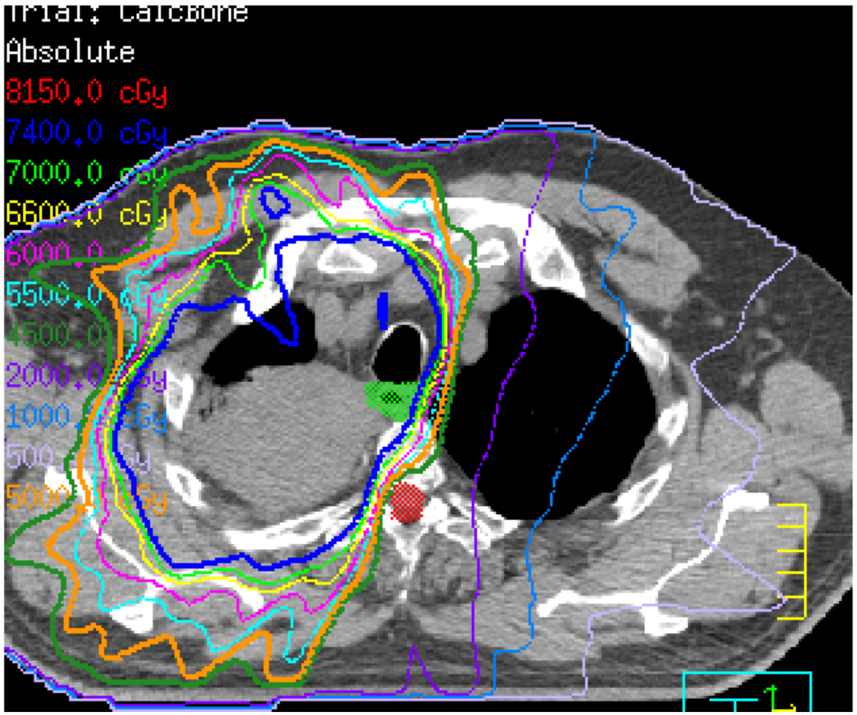
- We setup to structures (anatomy) but our goals are generally dose based
  - Ensure the target gets enough dose
  - Ensure the OARs don't get too much dose



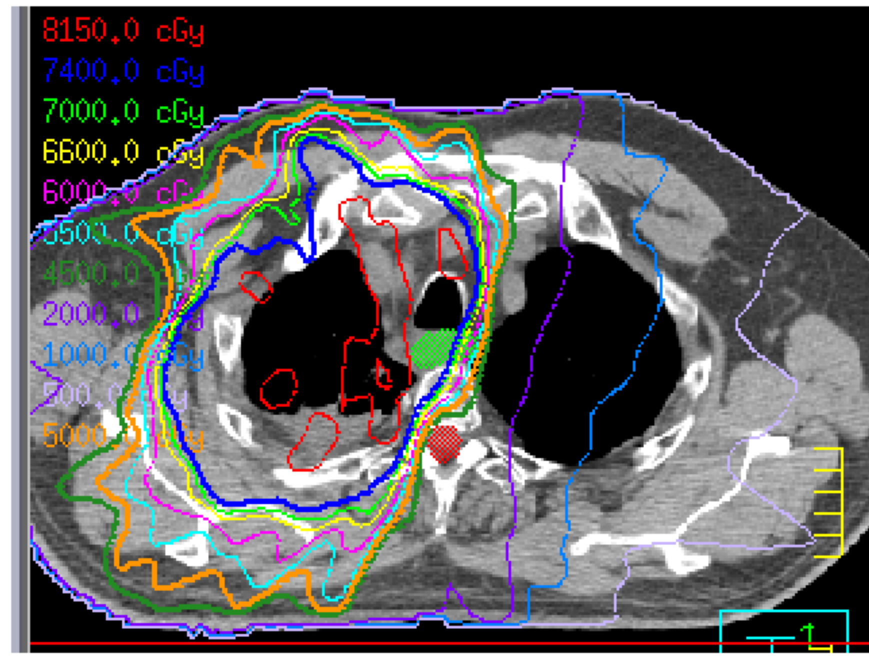
	Name	Width	Style	Color
☑	rt kidney	2.0	____	orange
☑	lt kidney	2.0	____	cyan
☐	Cord2	2.0	____	green
☑	liver	2.0	____	yellow
☑	residual masses	2.0	____	blue

☑	spleen	2.0	____	lime
☑	Vertebral Body	2.0	____	blue
☑	3060 (CCP Approv	2.0	____	yellow
☑	2900 (CCP Approv	2.0	____	magenta

The shape of Megavoltage Dose Distributions are relatively insensitive to local anatomical changes



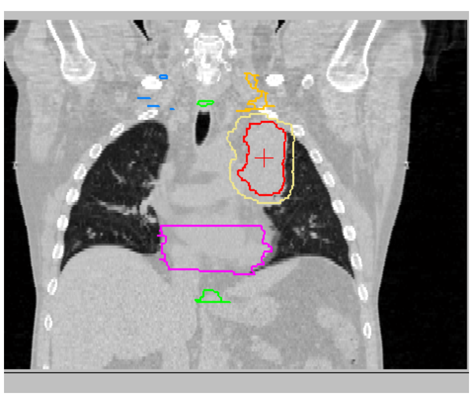
Dose calc on CT taken during 1rst week of treatment



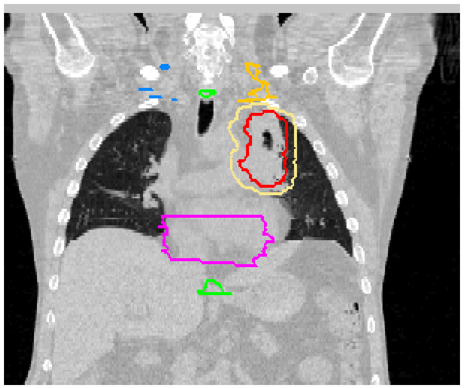
Dose calc on CT taken during last week of treatment

Study done at MDACC

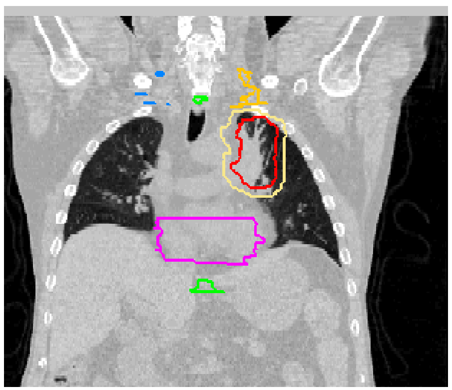
- We recalculated the doses based on weekly CTs taken as part of an IRB protocol for another purpose
- We compared dose metrics from the recalculated doses vs those from assuming the dose distribution did not change
  - Bone based alignment
  - Deformed the contours to match the changing anatomy)



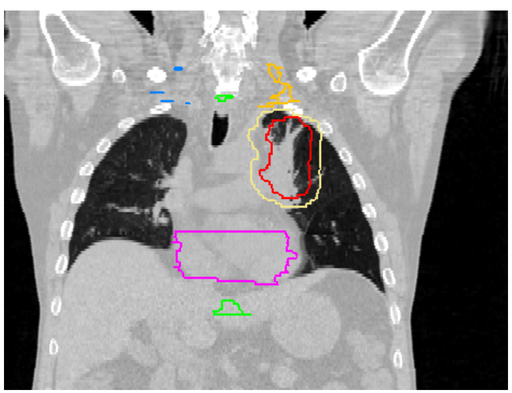
Simulation Scan



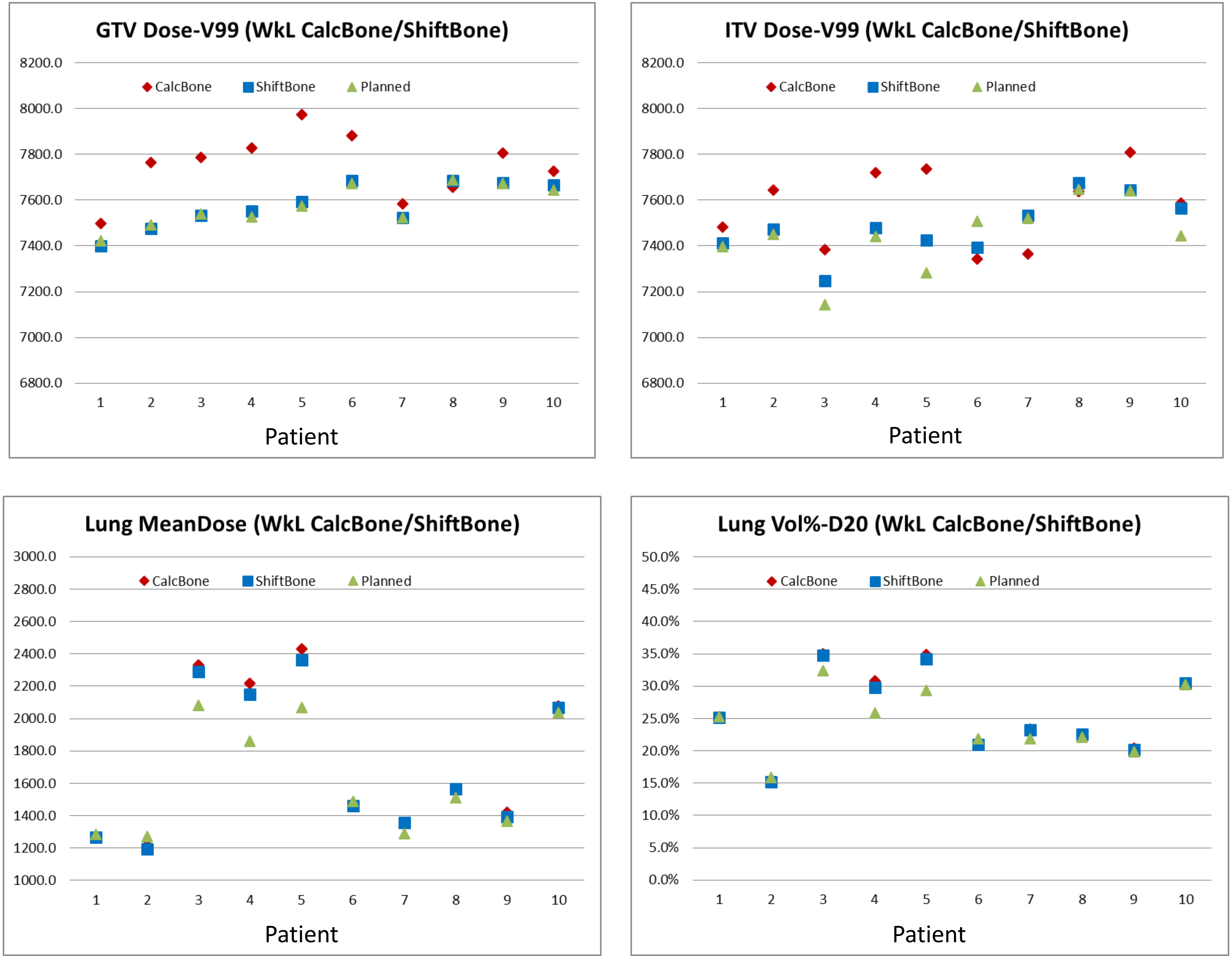
Week 3



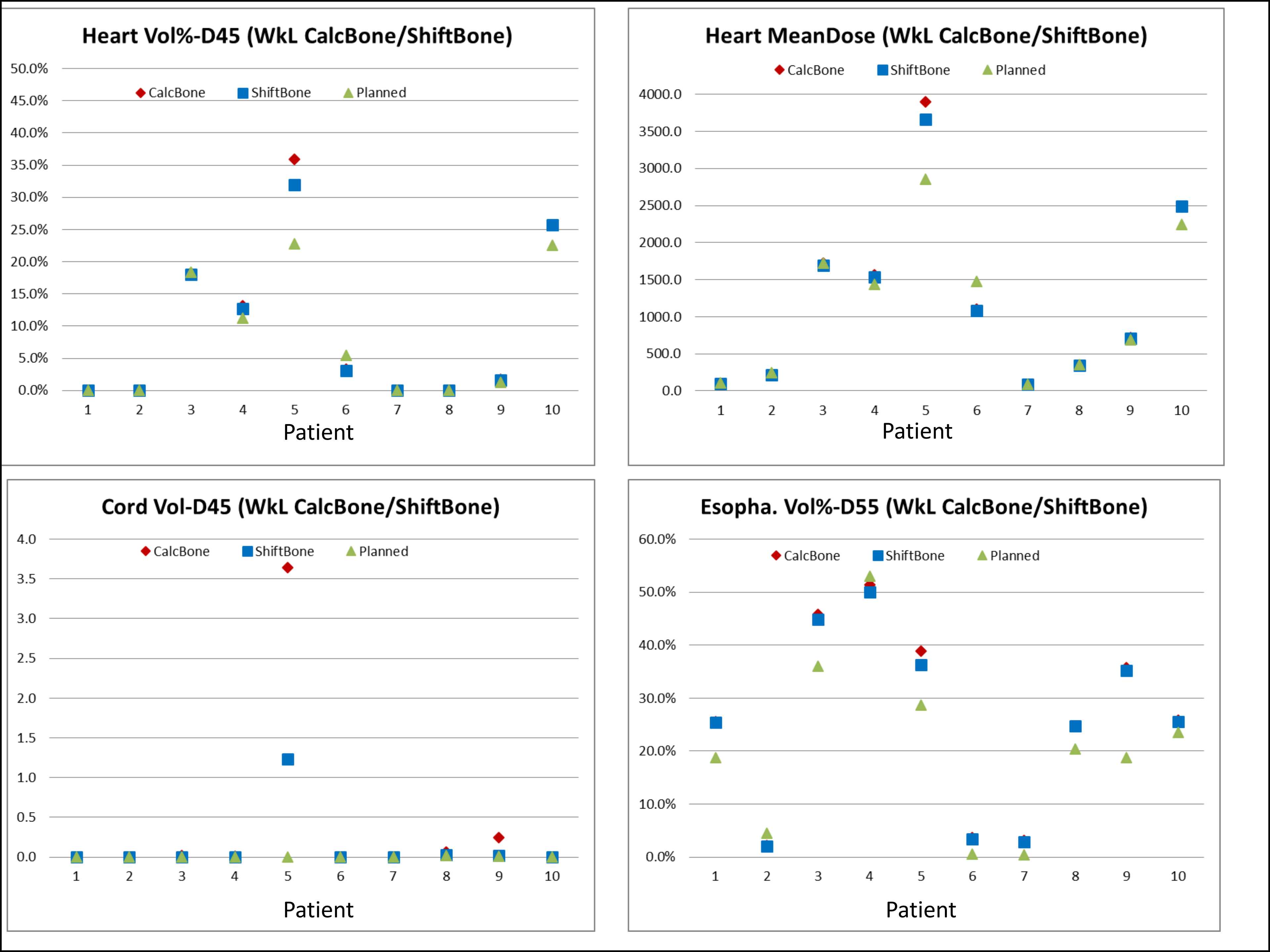
Week 5



Week 7



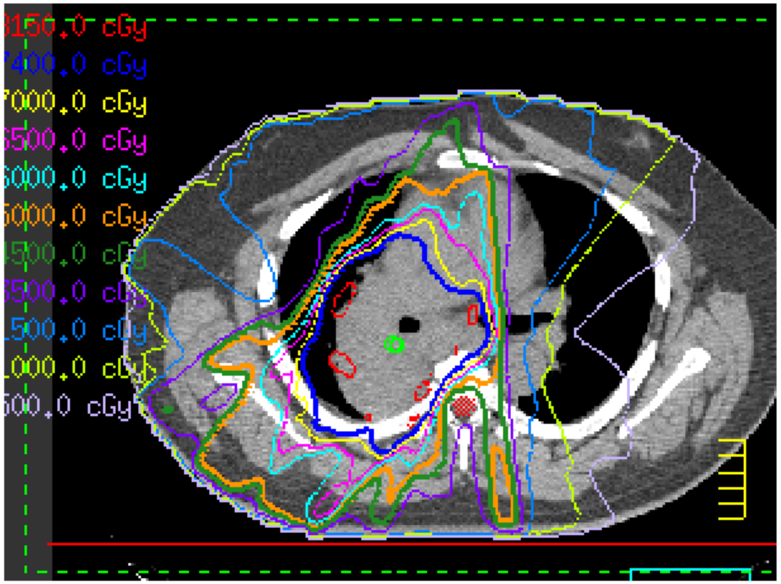
GTV Dose-V99 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
8200.0
8000.0
7800.0
7600.0
7400.0
7200.0
7000.0
6800.0
1 2 3 4 5 6 7 8 9 10
Patient
ITV Dose-V99 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
8200.0
8000.0
7800.0
7600.0
7400.0
7200.0
7000.0
6800.0
1 2 3 4 5 6 7 8 9 10
Patient
Lung MeanDose (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
3000.0
2800.0
2600.0
2400.0
2200.0
2000.0
1800.0
1600.0
1400.0
1200.0
1000.0
1 2 3 4 5 6 7 8 9 10
Patient
Lung Vol%-D20 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1 2 3 4 5 6 7 8 9 10
Patient


Heart Vol%-D45 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
1 2 3 4 5 6 7 8 9 10
Patient
Heart MeanDose (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
1 2 3 4 5 6 7 8 9 10
Patient
Cord Vol-D45 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1 2 3 4 5 6 7 8 9 10
Patient
Esopha. Vol%-D55 (WkL CalcBone/ShiftBone)
CalcBone
ShiftBone
Planned
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
1 2 3 4 5 6 7 8 9 10
Patient

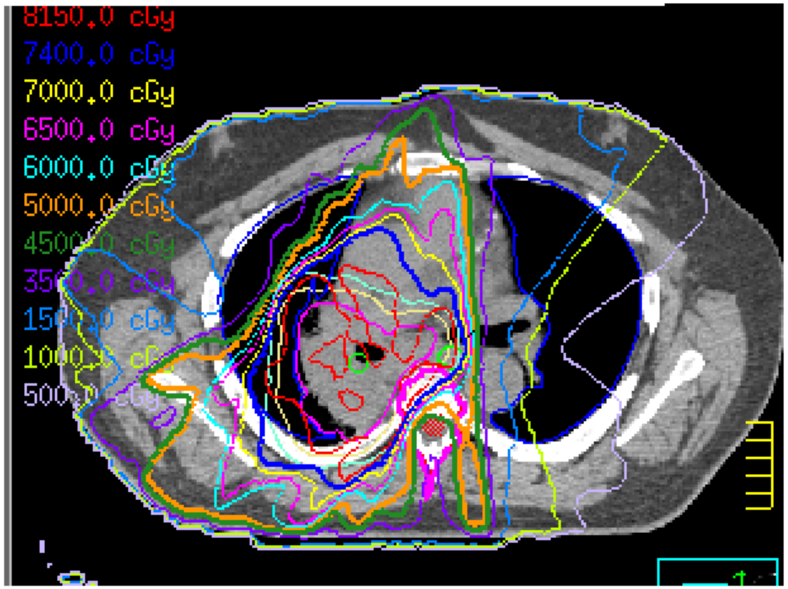
What we found

- Target coverage can be assessed by shifting the dose distributions
- Critical structure doses
  - In general accurate
  - Can have a higher uncertainty in areas of step dose gradients (suggesting PRVs are needed)

Wk1

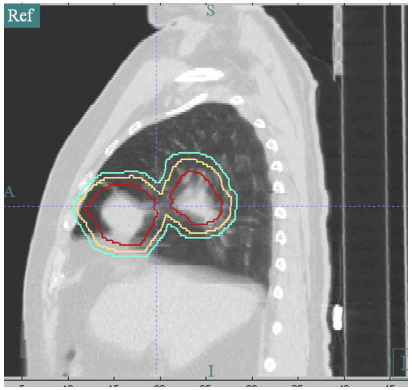


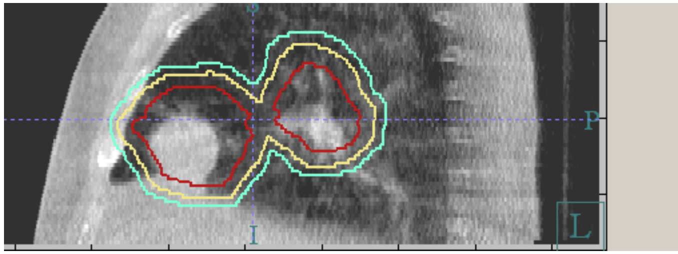
WkL



Compromise set ups

- Between different ROIs
- Treat the tumor or avoid the OAR
- Rotations
- Deformations



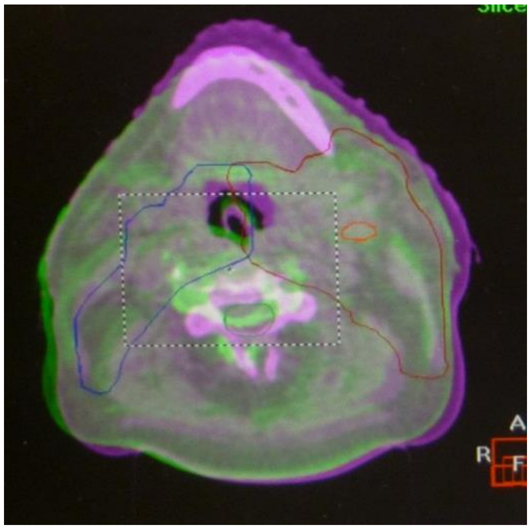


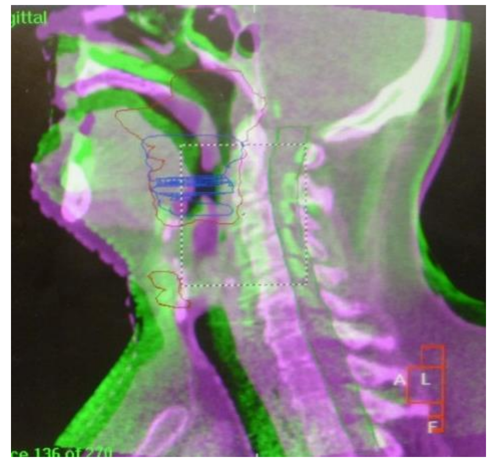
Simulation

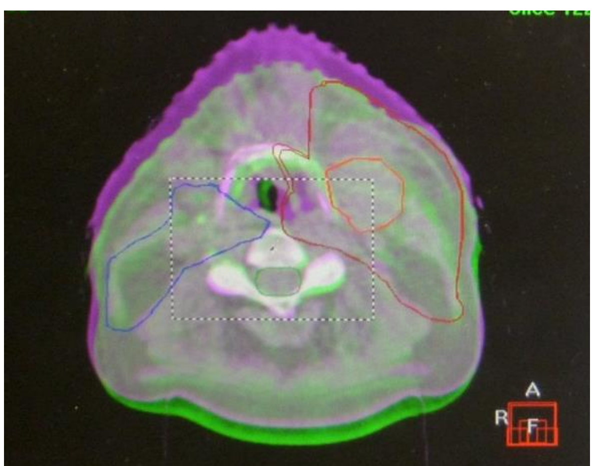
Treatment

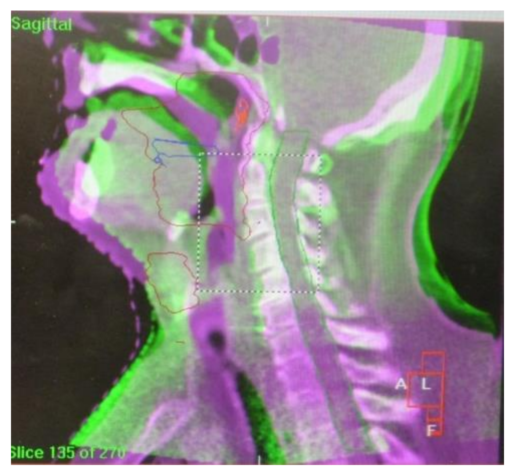
Which GTV should be used for setup

For Head and Neck you need to choose a set-up area if the head tilt cant be matched to simulation









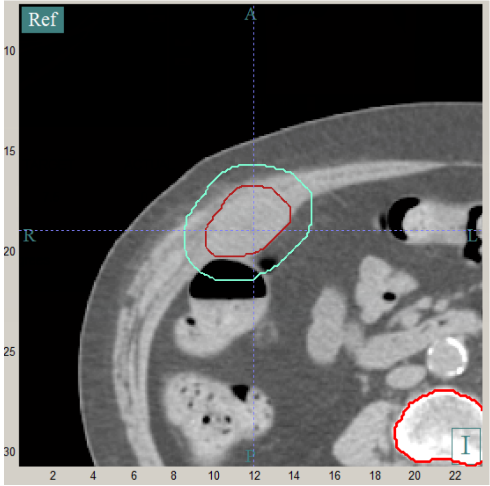
Bucci

Is 3D imaging always better?

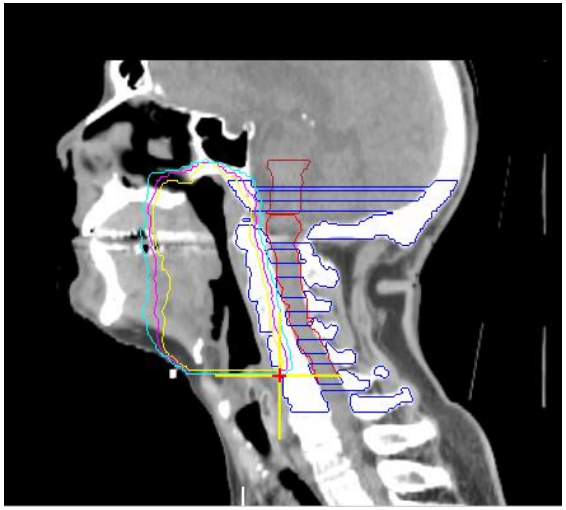
- Longer to acquire
- Longer to analyze
- Therapists are not trained to look at the information
  - Need discreet bits of data to analyze – decide what you are looking for, what you want therapists to looks for, what your thresholds for calling MD are
  - Slows down your practice

Standardization of IGRT instructions

- IGRT involves various choices and trade-offs
- There have multiple opportunities for the Attending and the RTT to have different interpretations of the IGRT goals
- There needs to be a standardized method to communicate the IGRT goals and results between the Attending and the RTTs



Pattern: CT simulation, IMRT QA, daily CBCT to tumor



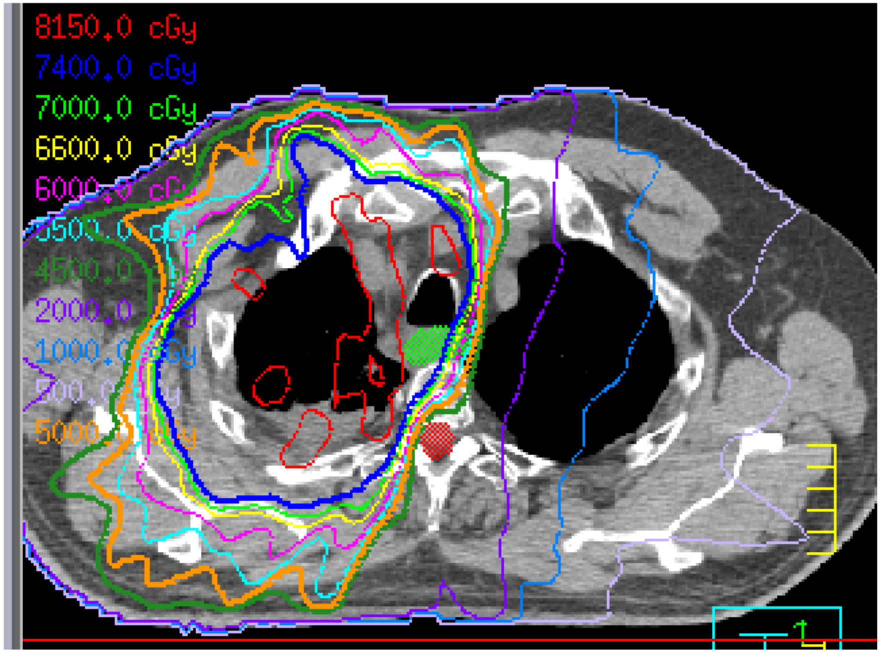
Pattern: IMRT qa, CBCT setup daily, see note for bid

Never assume something is obvious

Real sign posted at a major Cancer Center

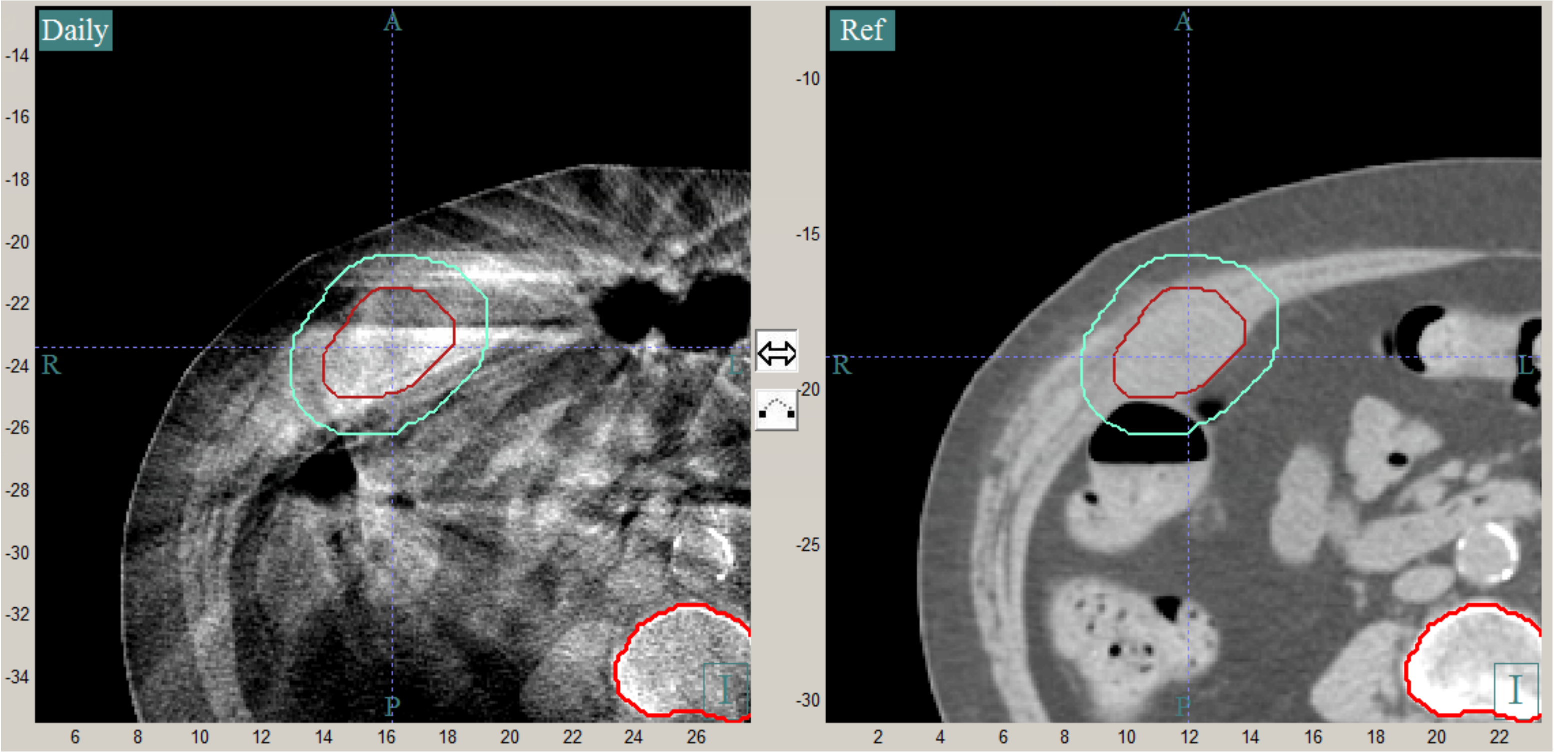
Communication

- Standardization of set-up volumes
  - Both targets and OARs
- Clear and consistent instructions to therapists on
  - What they are setting up to (ex. label a contour as “SS”)
  - When to call MD (ex shift bone and soft tissue)
  - Any avoidance rules



Training: Physicians

- IGRT allows for margin reduction (If done correctly)
- Use the right setup techniques for each patient
  - Daily kVP for conformal avoidance of cord
  - Daily CBCT for hypo-fractionated (SRT) body
  - Weekly CBCT to look for tumor changes and trigger a replan
  - Understand the limitations of the technology



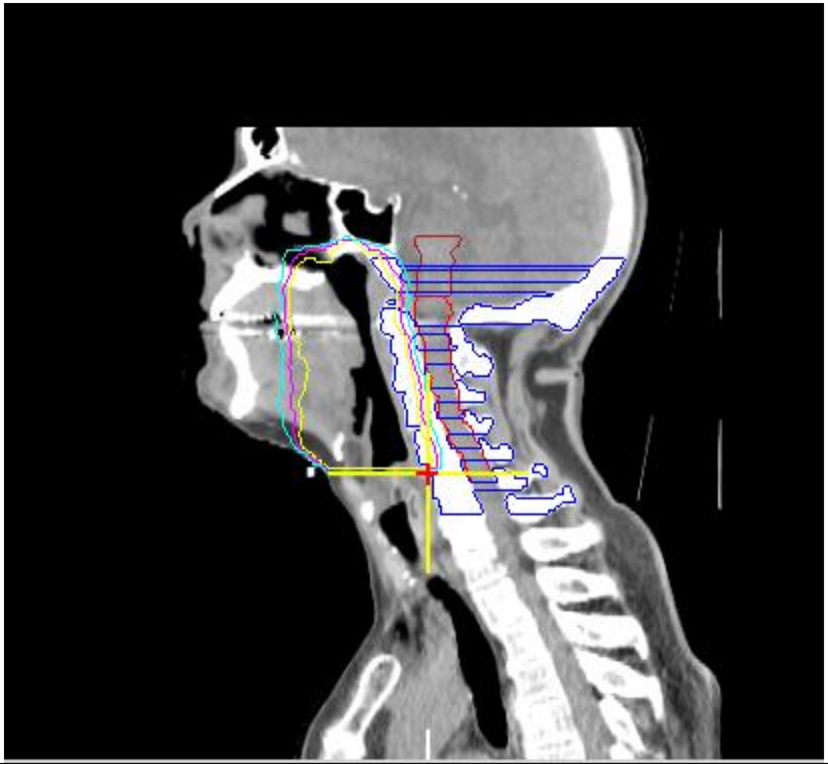
Example of Guidelines for Physicians

- The radiation prescription should include the IGRT instructions and should indicate
  - Type of IGRT
  - Frequency of IGRT
  - Setup Surrogate – or avoidance structure

- Example:
  - Daily kVp (Bone) Weekly CBCT (bone) notify Dr if “63 Gy” doesn’t cover GTV
  - Daily CBCT (GTV)
  - Daily CBCT (avoid major vessel then cover GTV)
  - Daily CBCT (GTV, notify Dr. if “45 Gy” crosses the cord)

Training: Dosimetrist

- New steps to prepare imaging fields/CBCT fields for treatment
- Labeling of contours and choosing which contours to send to the treatment console
- Creation of Isodose line contours
- PTV margins as a function of setup technique



Example Guidelines for Dosimetry

- Volumetric (CT) Imaging: The Prefix SS (Setup Structure) should be added to the contour indicating the alignment structure for CBCT
  - Add any isodose lines needed to evaluate setup to the CT structure set
- Transcribe the imaging instructions into the setup instructions section (same place as isoshift)

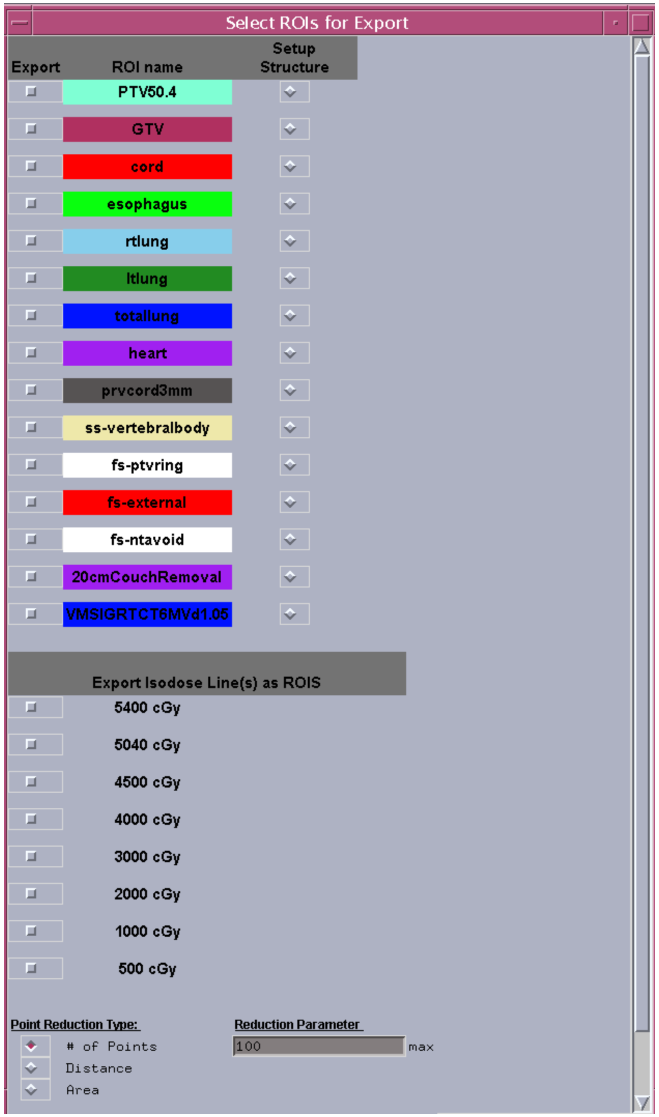
Setup Instructions

supine,orfit board/pad/mask, 9 degree wedge heel to pt, w. /NEW BLUE #2 headrest, wedge knees, arms down by sides, marks for alignment, see photos

1 shim

Tool developed at MDACC to help setup CBCT based IGRT

- We created a Pinnacle script to
  - Reduce Points (very important in Pinnacle Paintbrush created contours to reduce MOSAIQ/4DITC issues)
  - Choose structures for export
  - Create Isodose lies
  - Label setup structure



Example Guidelines for Physics

- Initial chart reviews should include
  - Ensuring the IGRT instructions are consistent with the treatment
    - Is the correct setup structure (SS) being used
  - Ensuring that the imaging instructions match the labels in the CBCT structures and/or DRRs.

- Ensure the reference images are of sufficient quality and little or no extraneous contours are sent to the treatment machine

Training: Therapists

- Operation of new systems
- How to take good images/what anatomy to include
- Interpretation of 3D images
- Dose management (don’t retake CT due to computer problems)

Example Guidelines for RTTs

- On the first day: Review the prescription for imaging instructions and ensure they understand what the goal is for the IGRT and that the CT structures and/or DRRs are labeled correctly to help them accomplish these goals
- On each day of imaging ensure the correct setup surrogate is used.
- For Volumetric setup
  - Ensure there are no un-expected conflicts between various setup goals
    - If weekly CT ensure that setting up on the bony anatomy used in the daily projection X-ray CT does cause the tumor to be outside of the PTV. If it does contact the attending for further instructions.
  - Ensure avoidance structures are outside the high dose region.

Steps to Implement better communication

1. Identify various IGRT scenarios
2. Develop communications that would cover these scenarios
3. Create guidelines
4. Train staff (Physician, Physicist, Dosimetrist, RTT) on the guidelines
5. Implement the guidelines
6. Audit the staff on the usability of the guidelines and revise as necessary

Examples of IGRT scenarios

1. Daily kVp and weekly CBCT: Instructions need to enable the RTTs to know if using the boney anatomy as the setup surrogate is adequate for daily treatments 1) is the CTV still covered 2) Are the OARs still spared
2. Daily CT: Instructions need to indicate the setup surrogate and avoidance structures and give guidance on what to do if there is a conflict
3. Daily kVp projection X-rays setup on fiducials: Instructions need to indicate fiducials should be used and what do if there is a large disagreement between various fiducials and/or between the fiducials and boney anatomy.

Establish what happens at the machine

- How often does the MD look at the images? (real time? End of the day?)
- What does the therapist set up to?
- Clear and consistent action points
  - Shift vs treat
  - When to call MD

IGRT - steps

- Contouring – establish your department-specific PTV (what is your set-up error for each site, with and without daily imaging, and which type of imaging?)
- Which contours get transferred to machine
- Instructions to therapist - Set-up to what?
- Action point – when to call md
- Change in treatment over time with what you learn

Summary

Room CT has the potential to improve the quality of care

- Requires understanding of margins
- Requires an understanding of imaging
- Requires good communication
  - Simulation – Dosimetry - Treatment
- Requires comprehensive training
  - RTTS
  - Dosimetrists
  - Physicists
  - Attendings

Proper use of IGRT (especially in room volumetric Imaging) requires your most import asset: Time

TABLE III. Estimated human resources required for image guidance using CT-based IGRT technologies. Estimates are obtained from the collected experiences of the task group members. More time is required when performing commissioning and quality control testing of 2D functions on some platforms.

Activity	Responsibility	Time	Notes
Acceptance testing and commissioning	Physicists	2.5 days	
Education	Physicists	2 days	First install only
	Therapists	2 days	First install only
	Dosimetrists	2 days	First install only
Operation	Therapists	5 mins/patient	Each treatment with IGRT; includes image acquisition and evaluation
	Dosimetrists	10 min/patient	Data transfers to imaging platform
Review of images	Physicians	5 min/scan	0 when performed by therapists
Daily quality control tests	Therapists	10 min	
Monthly quality control tests	Physicists	1–2 h	
Annual quality control tests	Physicists	2–4 h	
Continued clinical support	Physicists	0.05 full-time equivalent position	Ad hoc activity

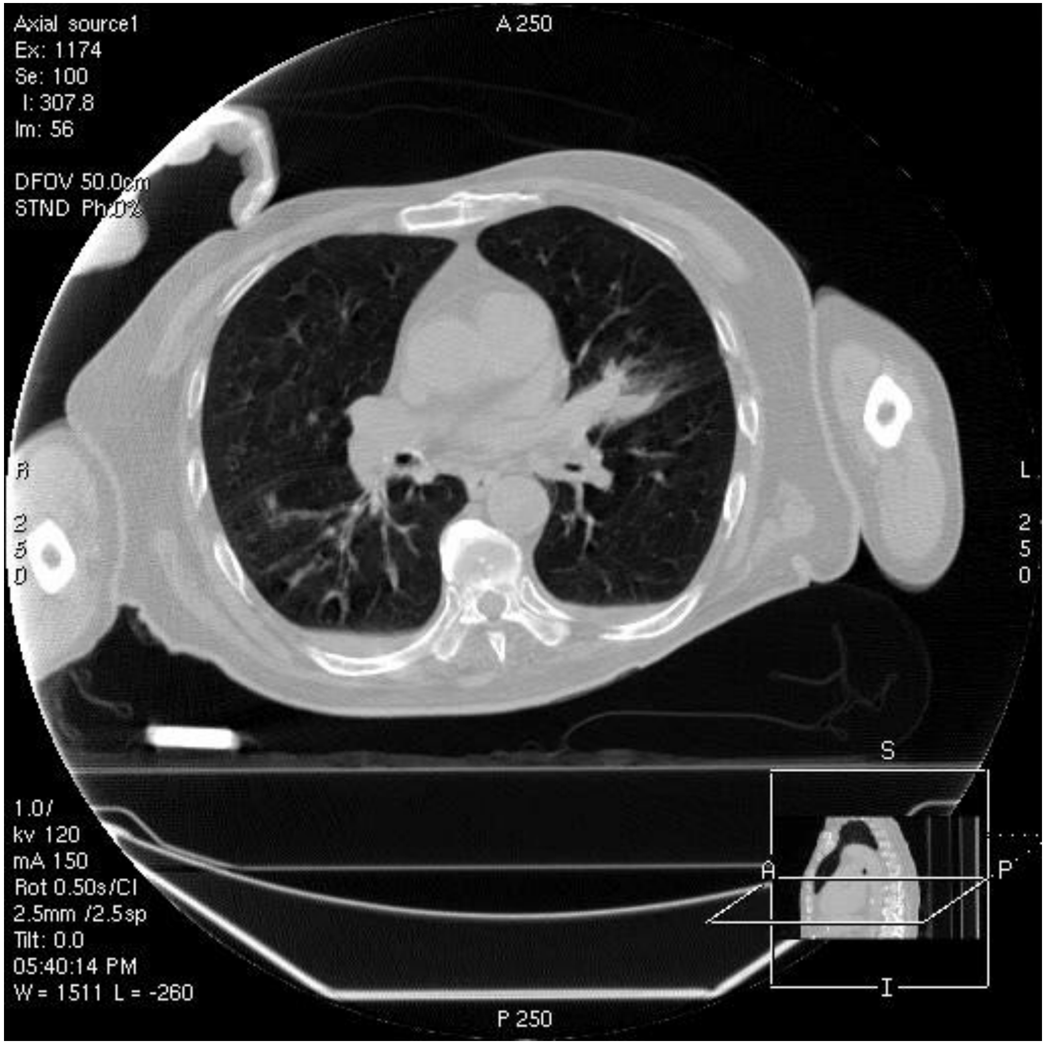
Quality assurance for image-guided radiation therapy utilizing CT-based technologies: A report of the AAPM TG-179

Jean-Pierre Bissonnette[a)]
Task Group 179, Department of Radiation Physics, Princess Margaret Hospital, University of Toronto, Toronto, Ontario, Canada, M5G 2M9

These estimates are probably too low especially with the lack of manufacture's tools to optimize setup and communication for 3D-3D matching

Thank You

- Kara Bucci, M.D.
- Laurence Court, Ph.D.
- Leifi Joy Zhang, Ph.D.
- Rajat Kudchadker, PhD
- Karl Prado, Ph.D.
- Lei Dong, Ph.D.
- Patricia Lindsay, Ph.D (PMH)



THE UNIVERSITY OF TEXAS
MD Anderson ~~Cancer~~ Center
Making Cancer History®