On-Board Imaging System: Implementation and Quality Assurance Procedures

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Presentation Outline

- On-Board Imaging (OBI) System as IGRT Tool
- Clinical Implementation of OBI
- Suggested QA Procedures for OBI and Cone Beam CT (CBCT)
- Summary

IGRT and IMRT

- Clinical use of IMRT requires precise localization of both target and normal tissues at the planning and treatment stages
- Image Guided RT (IGRT) is targeting the tumor using images with patient in treatment position immediately prior to or during treatment
- Goal of IGRT is to manage inter- and intra- fraction motion to reduce margins and optimize treatment designs

Benefit of Image guided radiation therapy (IGRT)

- Interfractional motion:
  - The change in target position from one fraction to another (setup error, and target motion
- Intrafractional motion:
  - The change in target position during treatment (target motion, and patient motion)

IGRT Strategies

- **On-line approach**

  making adjustment to the treatment parameters or position based on data within the current txt session

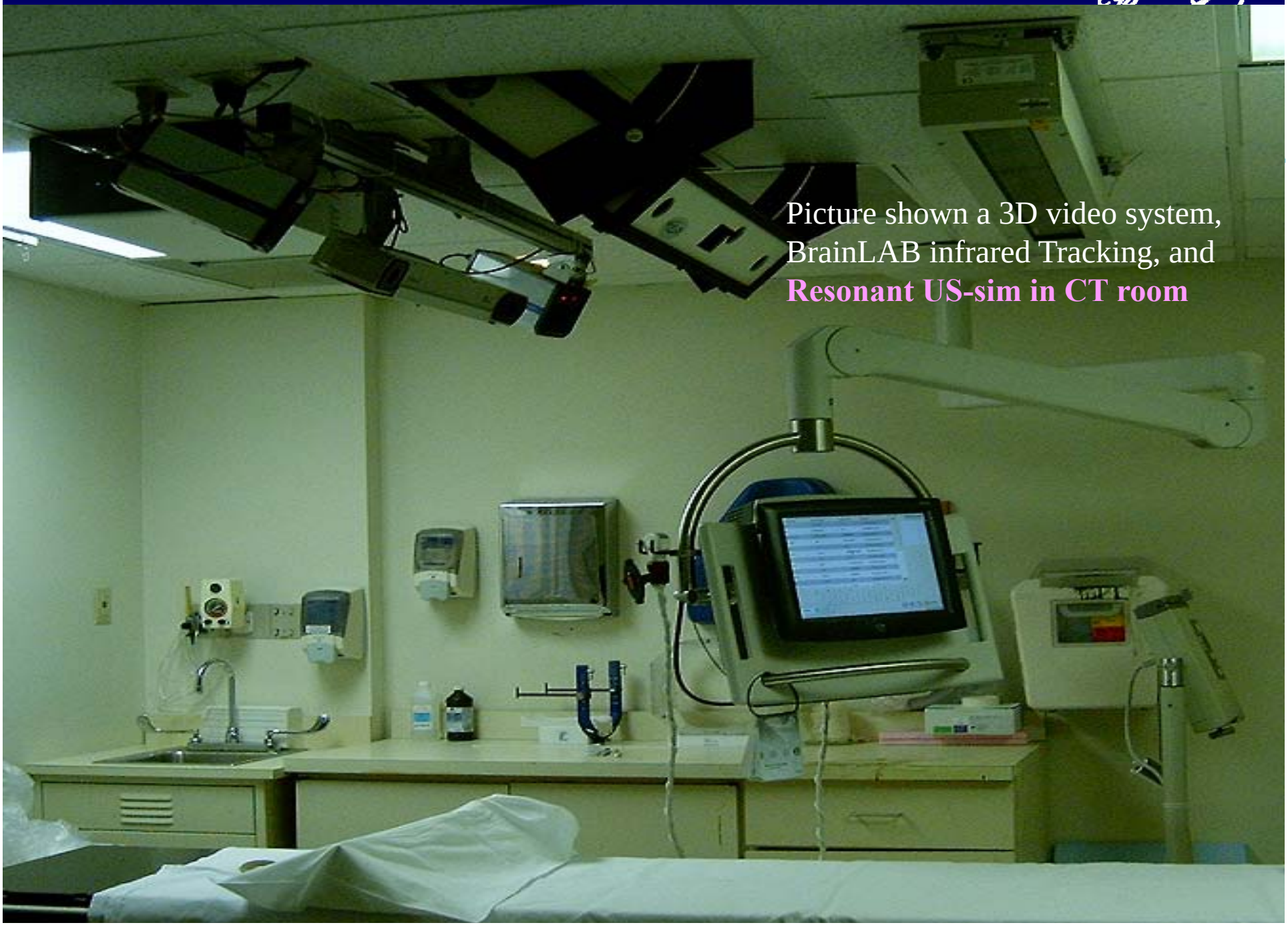
- **Off-line approach**

  Intervention is the result of accumulation of data drawn from txt sessions

IGRT Approaches

- Film imaging acquired using conventional port films
- Electronic Imaging using EPID
- Video & surface Guided
- Digital Projection Imaging (Radiographic and fluoroscopic)
- CT Guided (Cone Beam CT, CT-on rails, MV CT)
- 4D (gating, tracking, breath hold)
- Marker localization and marker Tracking (seeds, coils, infrared, clips, electromagnetic beacons)

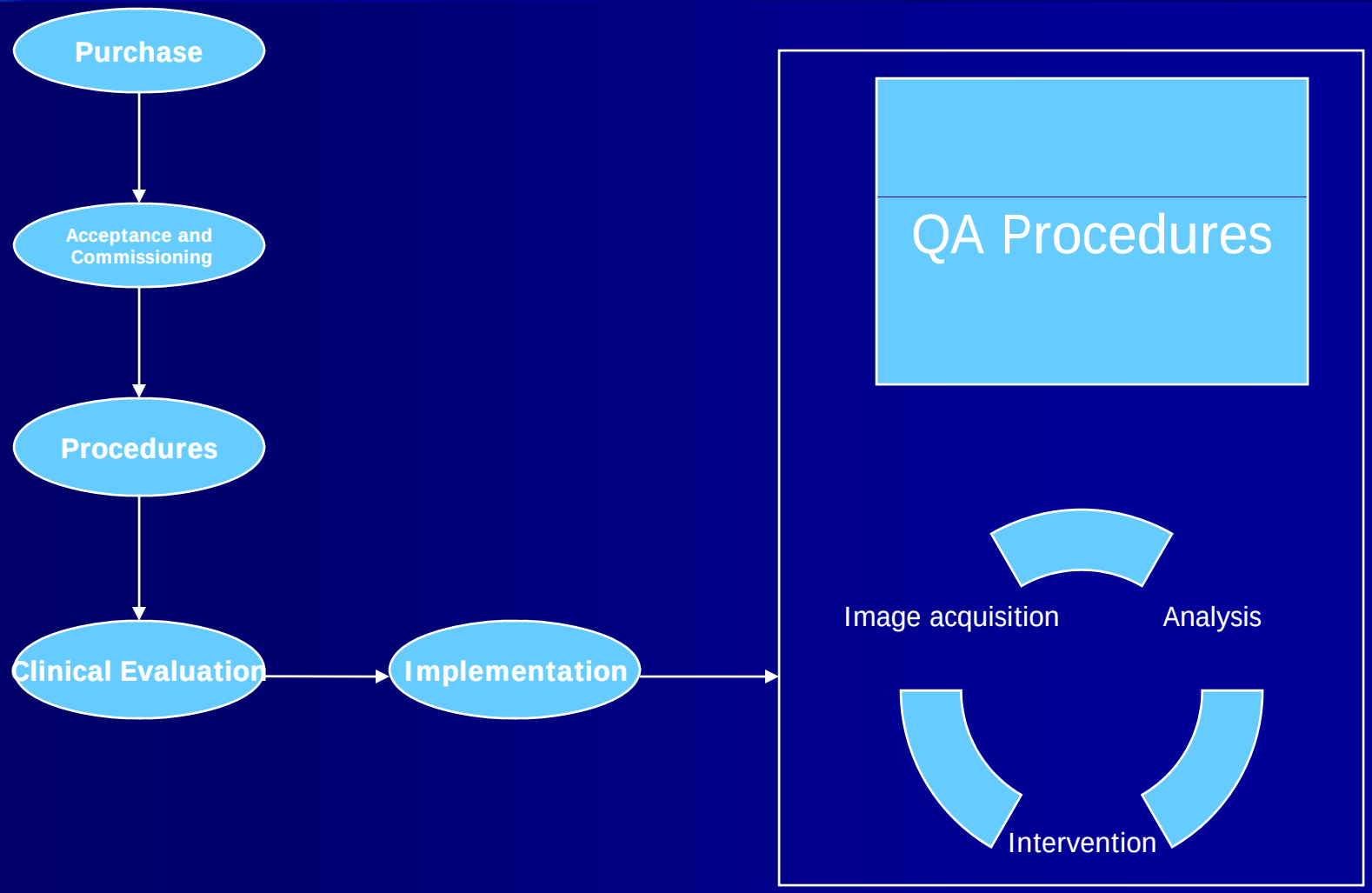
IGRT Tools at Henry Ford Health System


Picture shown a 3D video system,
BrainLAB infrared Tracking, and
Resonant US-sim in CT room

Identification of a suitable imaging IGRT tool

- Compromise of clinical objectives, product availability, existing infrastructure, and manpower
  - Clinical objectives (dose escalation/normal tissue sparing)
  - Structures of interest (target/surrogates)
  - Desired level of precision
  - Method of intervention/correction
  - Available treatment capacity
  - Application for all or some patients
  - Identification of individuals responsible for commissioning, QA, procedures
  - Structure development for responsibility delegation with respect to measurement, analysis, decision, and correction

Flowchart for Initiating IGRT



On-Board Imager

Downriver Center for Oncology

HFH Downriver Cancer Center

- Treat 60 patients/day
- ~70% IMRT
- 2 Varian LINACs; 2100C with EPID & 21EX with OBI
- Integrated solution with Varis 7, Eclipse TPS, and LINACs
- Philips single slice AcQSim large bore CT

Varian On Board Imager™ (OBI)

- Two robotic arms consisting of kilovoltage Xray source and detector
- Can obtain plain radiographs/ fluroscopic or with rotation can obtain cone beam CT images.

Varian OBI/CBCT System – Downriver Center

Linac Console

4DTC

KVS

MVD

KVD

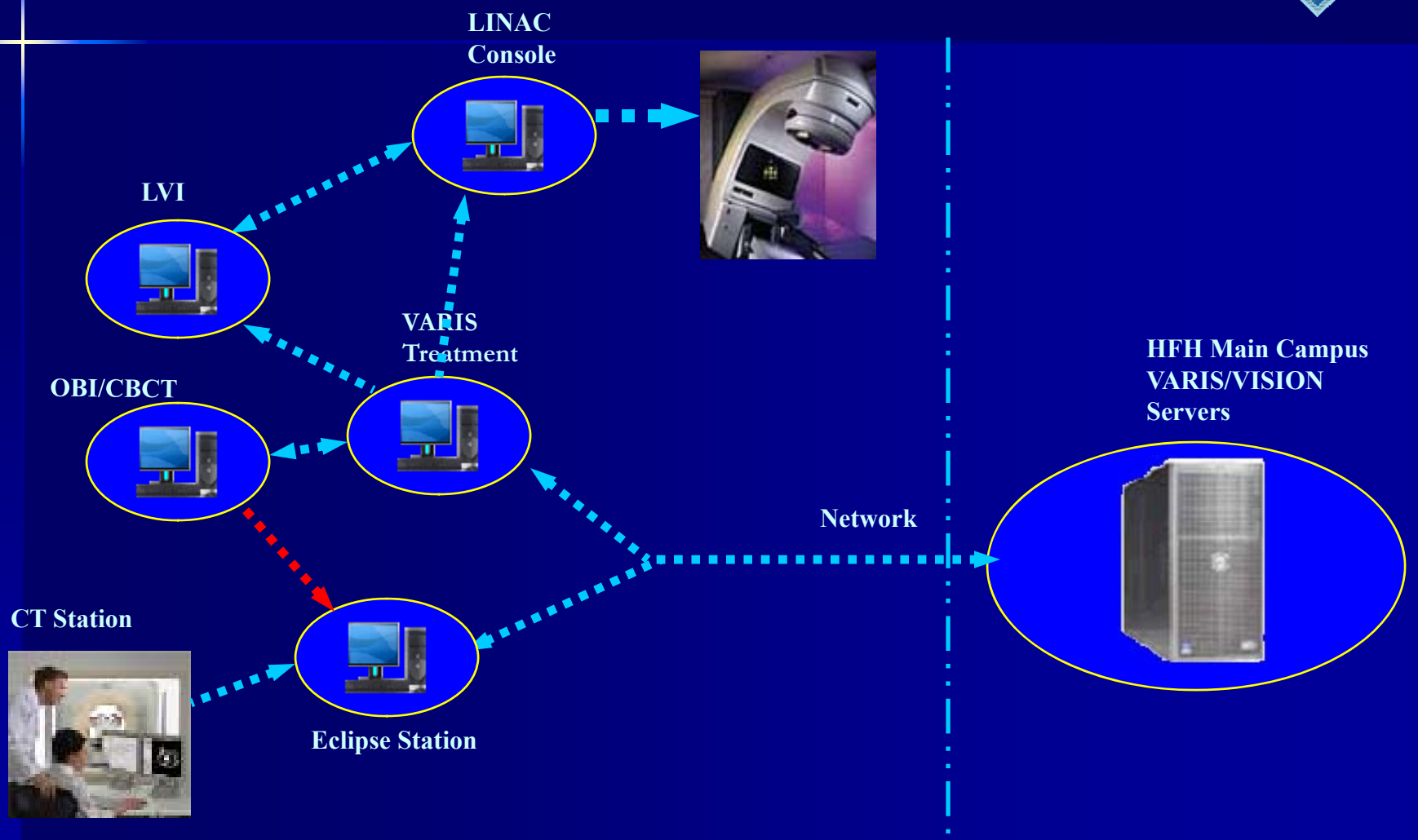
OBI/CBCT

RPM

OBI Workstation features

- Acquisition of KV images (radio and fluoro mode)
- 2D/2D automatic and manual matching of reference images to pair acquired images
- 2D/2D automatic and manual matching of reference images to pair of KV/MV images with implanted markers
- Qualitative verification of RPM gating using fluoroscopy
- CBCT Acquisition
- 3D/3D automatic and manual images fusion of CBCT to reference 3D images

Data Flow


LINAC
Console
LVI
VARIS
Treatment
OBI/CBCT
HFH Main Campus
VARIS/VISION
Servers
Network
CT Station
Eclipse Station

Commissioning and Acceptance Testing

- Shielding and room design considerations
- Safety and mechanical aspects
- Geometric calibration of systems
- Radiographic and fluoroscopic imaging system performance
- CT image quality
- Database and data transfer integrity

Training

- Just like any other new modality IGRT requires training
- Training of therapists to use OBI properly is the key to a successful launch of an IGRT program

OBI-IGRT Capabilities

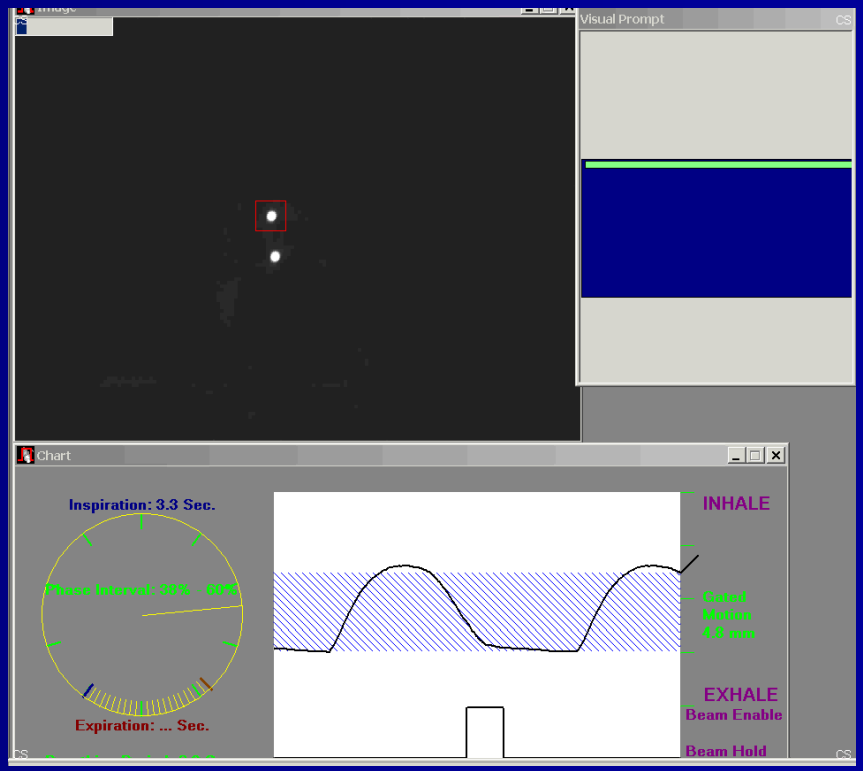
- Film imaging acquired using conventional port films
- Electronic Imaging using EPID
- Video Guided
- Digital Projection Imaging (Radiographic and fluoroscopic)
- CT Guided (Cone Beam CT, CT-on rails, MV CT)
- 4D (gating, tracking, breath hold)
- Marker localization and marker Tracking (seeds, coils, infrared, clips, electromagnetic beacons)

How IGRT

- RPM – Respiratory Gating System
- OBI – On Board Imager
- CBCT – Cone Beam CT

RPM

- Track patients' respiratory motion with external infrared-reflective marker block. Control intra-fraction motion.
- Correlation of internal motion and external motion
- Treatment time is also a consideration
- Time delay



CT time delay

Time delay study of a CT simulator in respiratory gated CT scanning

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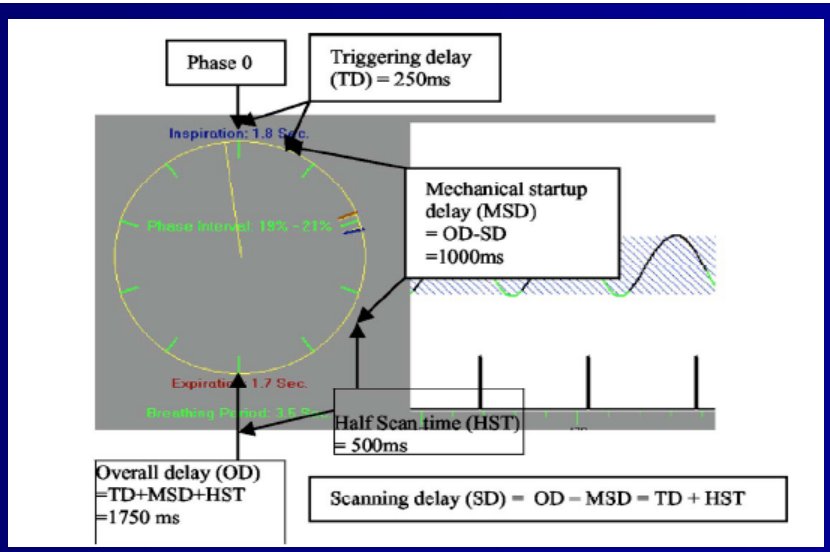
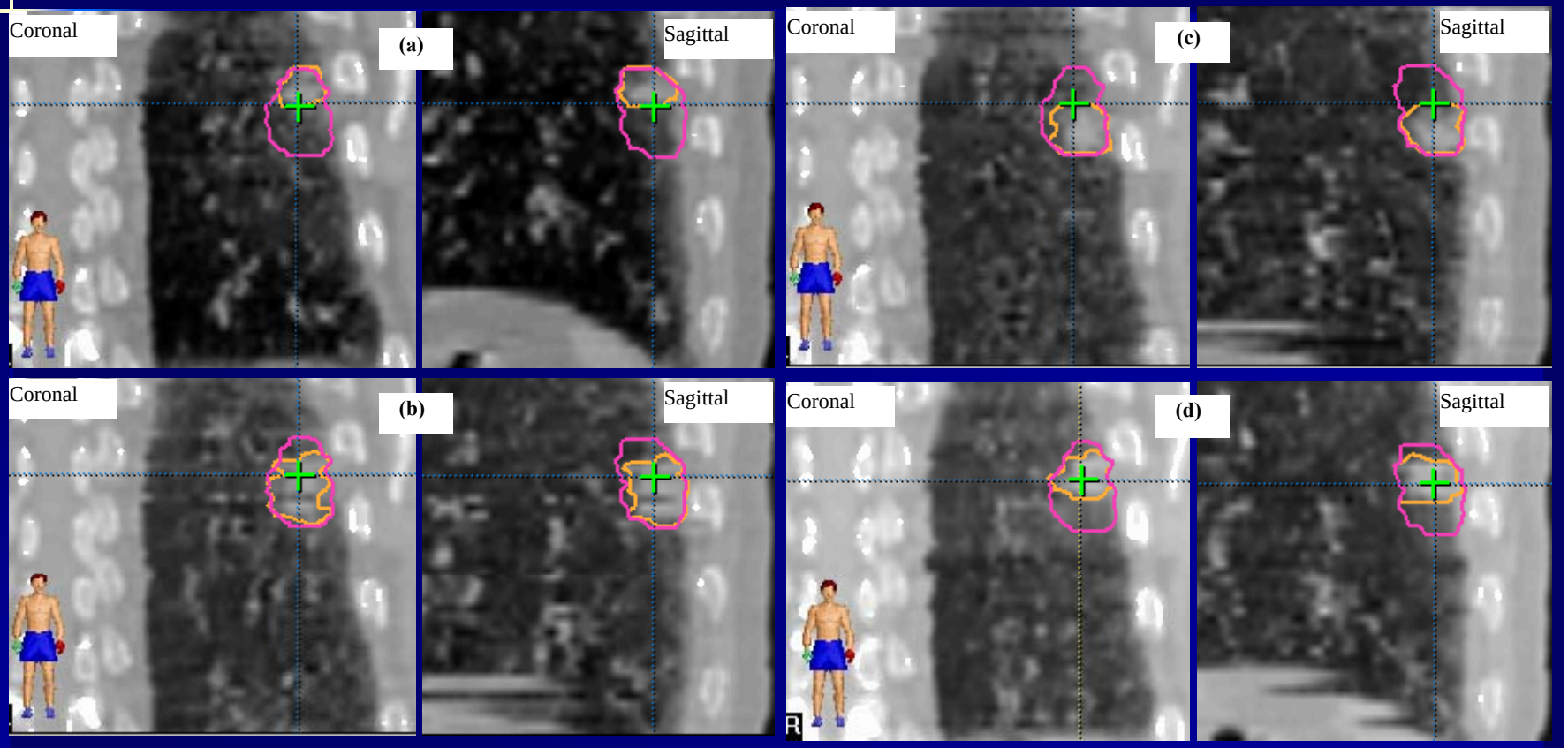
In respiratory-gated radiotherapy (RGRT), if the time delay in a computed tomography (CT) simulator and that in a linear accelerator (Linac) are different, the simulation and the treatment cannot be synchronized. In this study, we presented a technique to measure the time delay of the AcQSim CT simulator (Philips Medical Systems, Cleveland, OH) using Varian's Real-Time Positioning Management (RPM) system (Varian Medical Systems, Palo Alto, CA). A respiratory gating platform (REF 91150, Standard Imaging, Inc., Middleton, MI) was first set at the position of amplitude maximum (phase 0). Then a ball of 1.3 cm diameter was put on the platform and set at the CT laser. A single axial scan was acquired across the center of the ball without motion. Then the motion was turned on and single axial scans gated at different phases were acquired with a very narrow gating



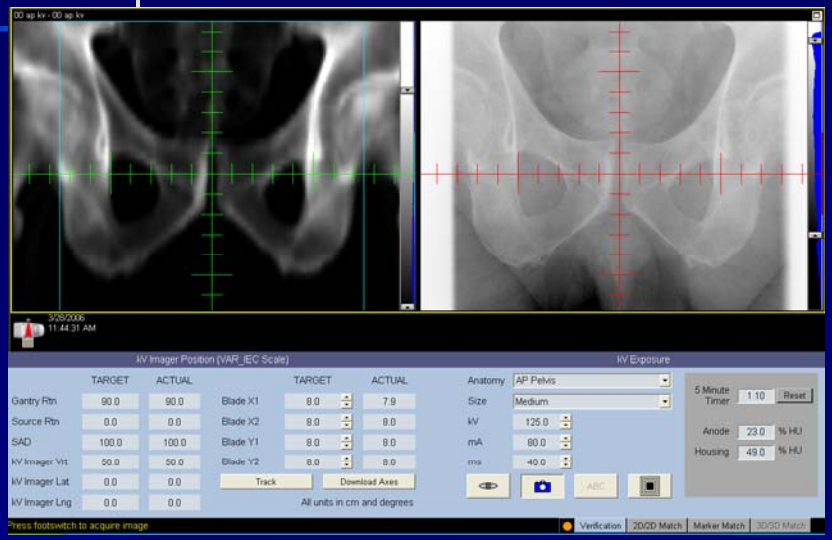
ITV Delineation with 4 phases gated CT



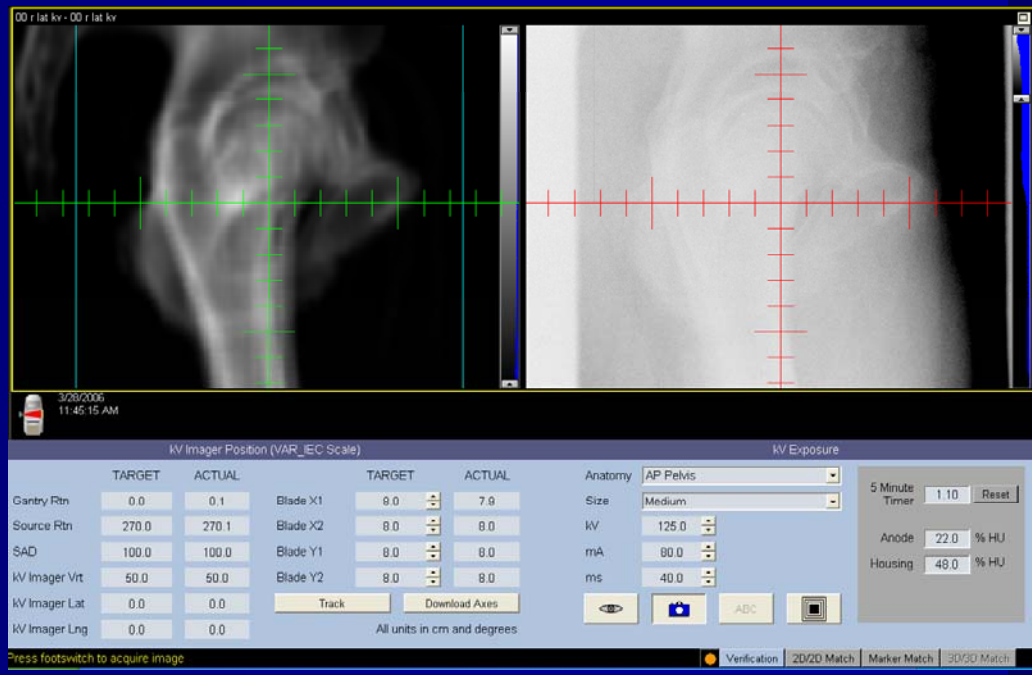
(a) Exhale, (b) Midphase, (c) Inhale, (d) Spiral

ITV encompassing all the visible targets in different phases

OBI

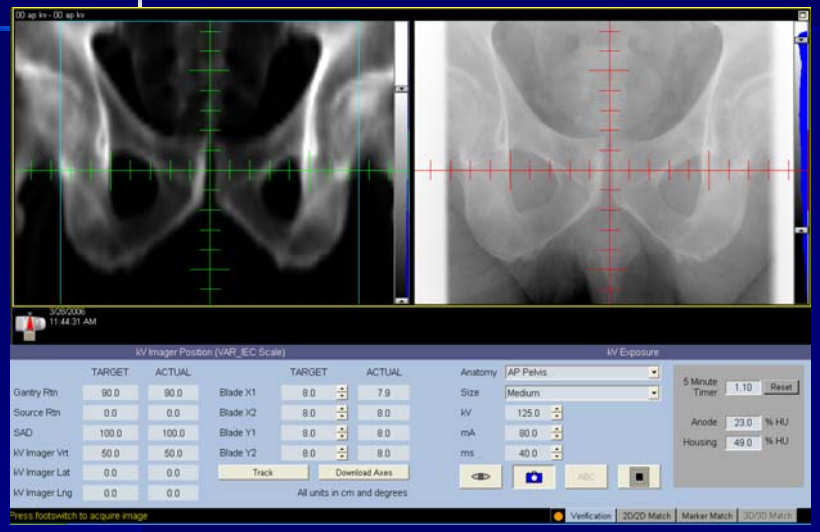


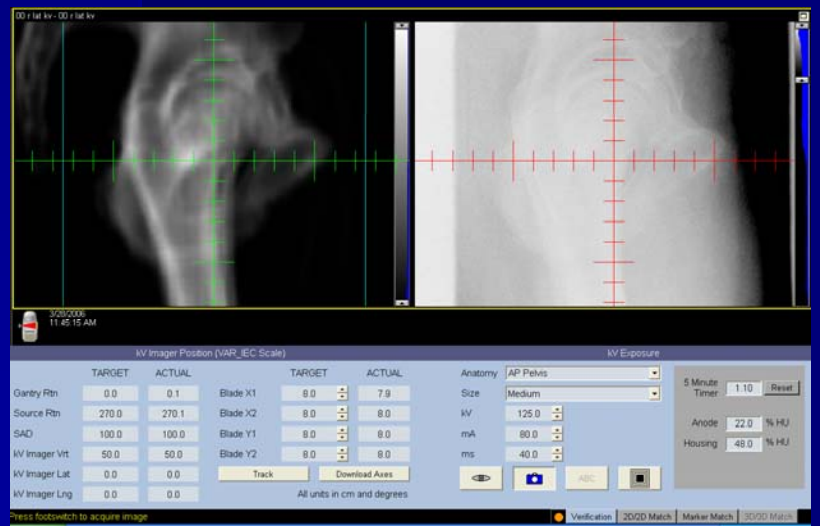
Orthogonal portal images – MV and kV image can be acquired without gantry rotation for AP and Lat online patient setup or KV/KV image pair



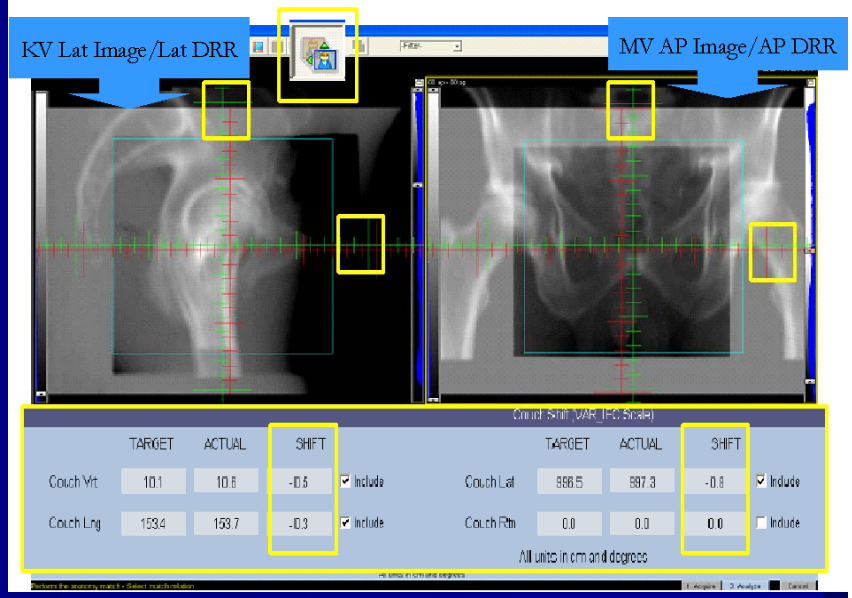
Couch position and angle can be corrected based on the 2D-2D matching between the portal images and DRR

2D/2D Image Registration





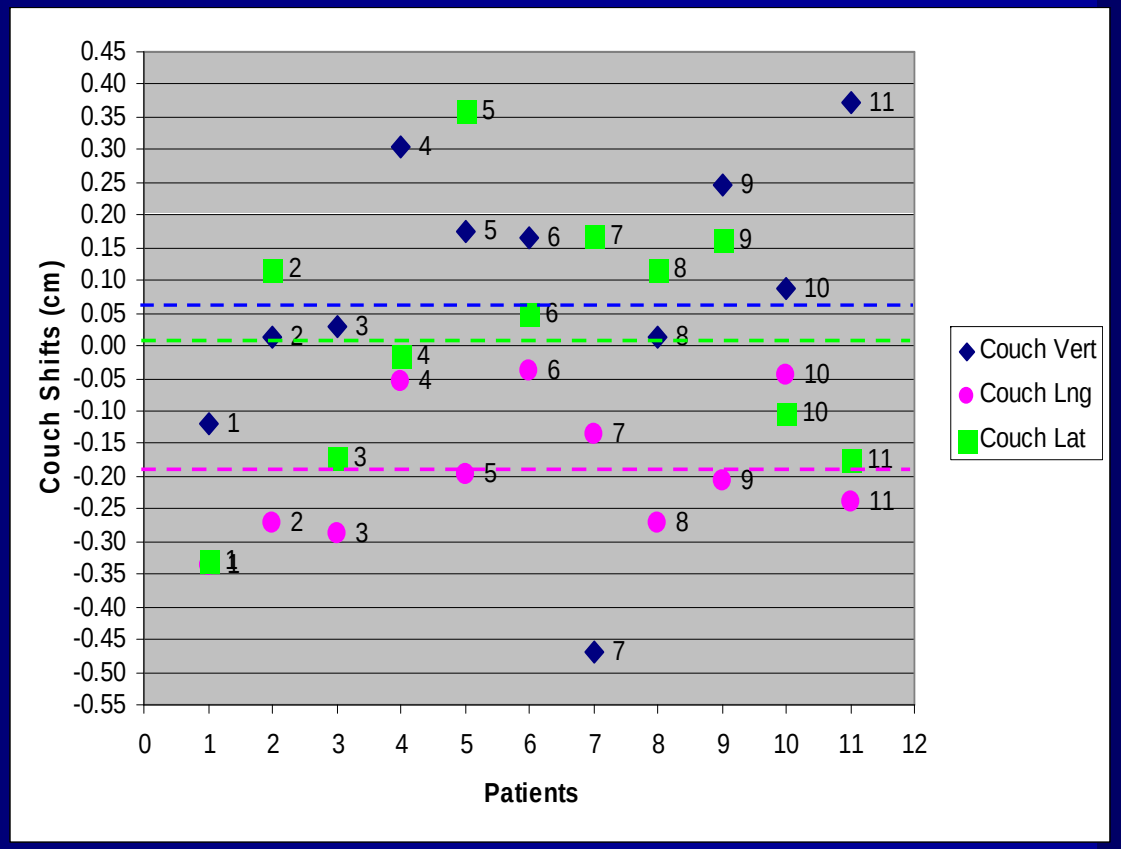
Matching & shifts



Patient Shifts Data

11 Prostate Patients Data (~2000 OBI data)

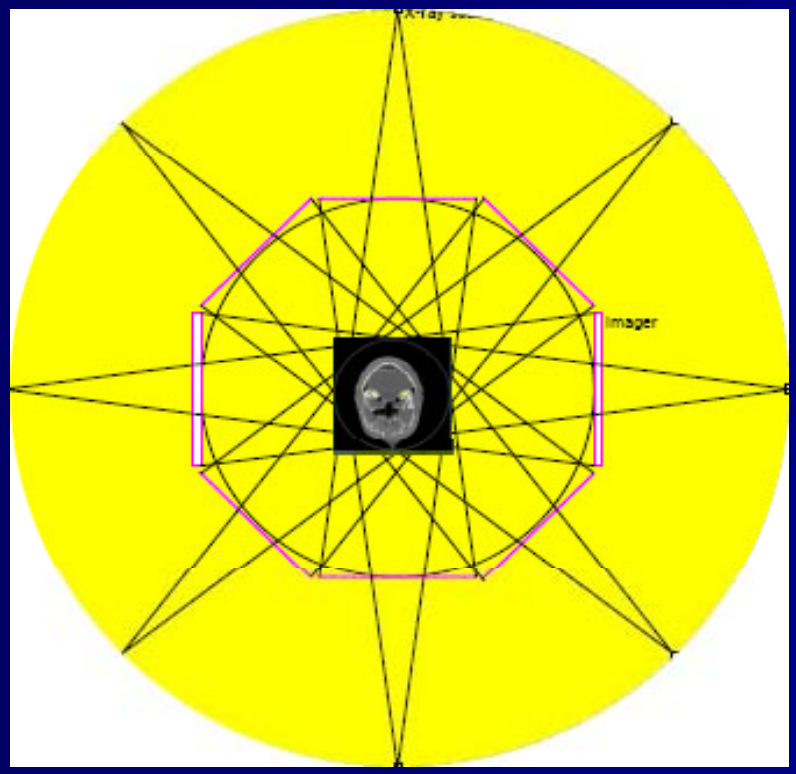
- Average translational shifts:
  - ✓ Vert: 0.07±0.65 cm
  - ✓ Lng: 0.20±0.27 cm
  - ✓ Lat: 0.02±0.43 cm



CBCT

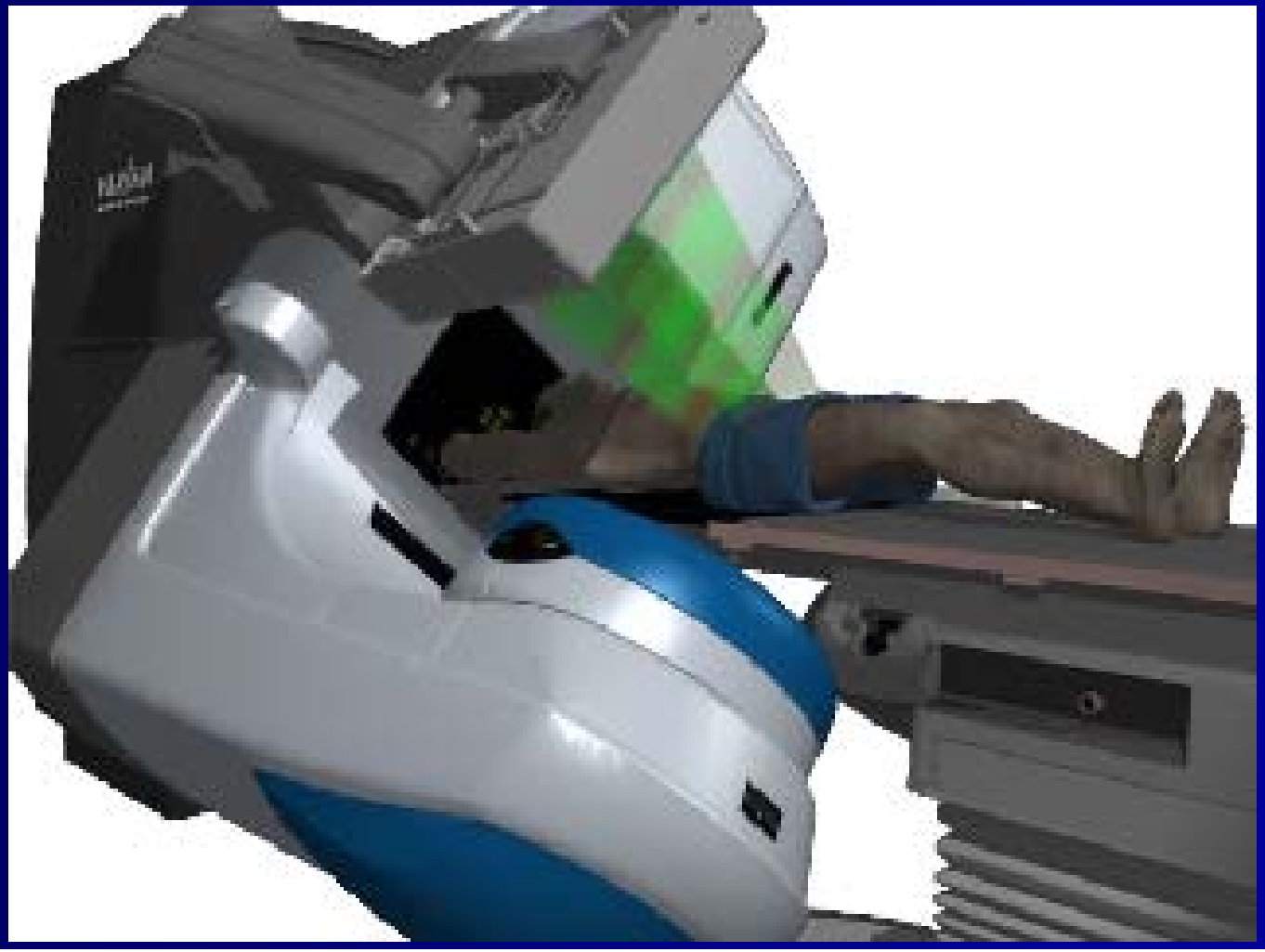
- CBCT is capable of acquiring and reconstructing 3D volumetric data in one gantry rotation with the patient in treatment position.
- Verification of target position now can be achieved efficiently and accurately using CT images.

CBCT – Techniques

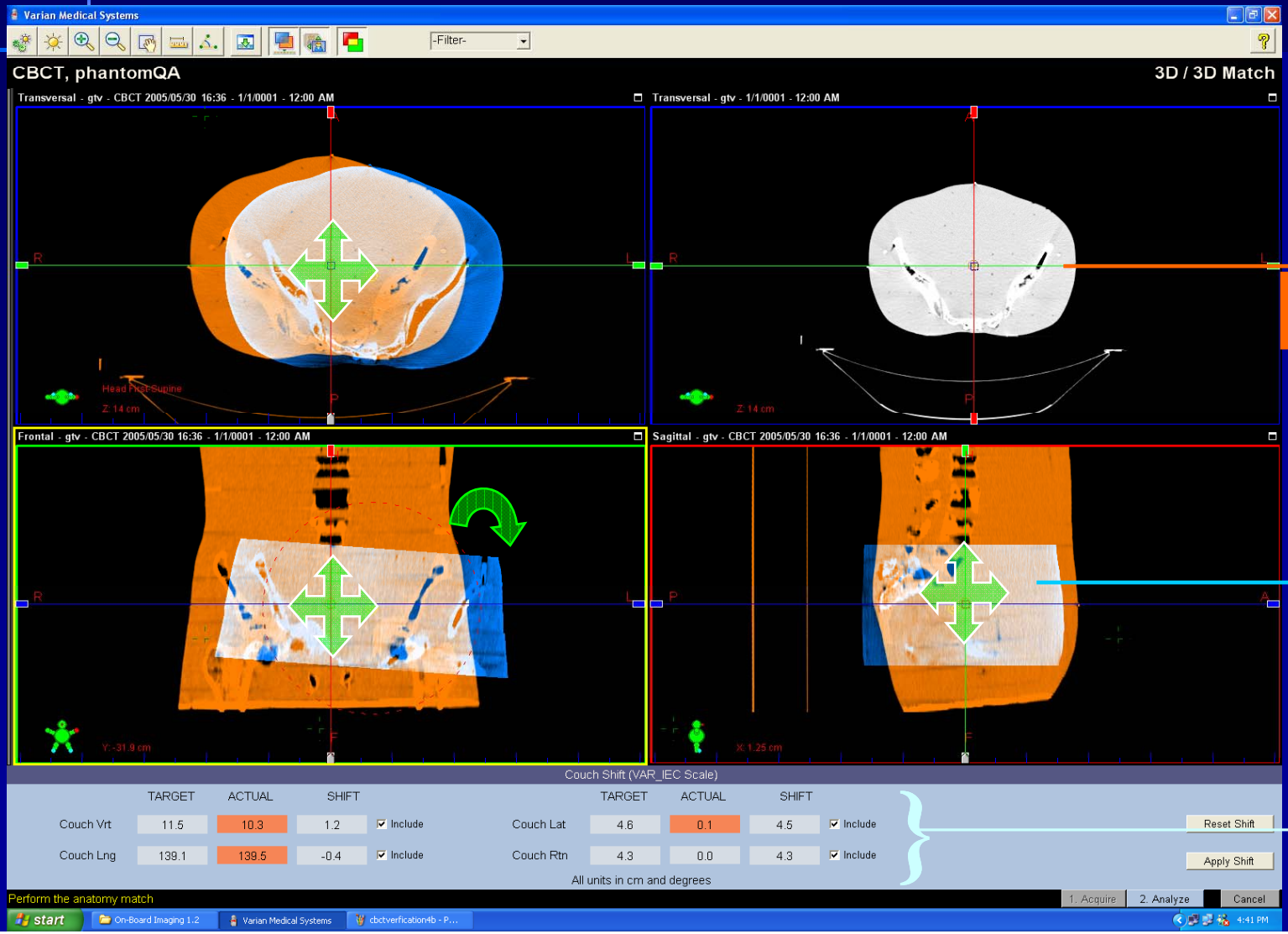


- 650-700 projections
- 370°gantry rotation
- 65 sec acquisition time
- ~2.5 mins total for acquisition and reconstruction
- Beam angle of 14°

CBCT Acquisition



CBCT: 4-Degree of Freedom

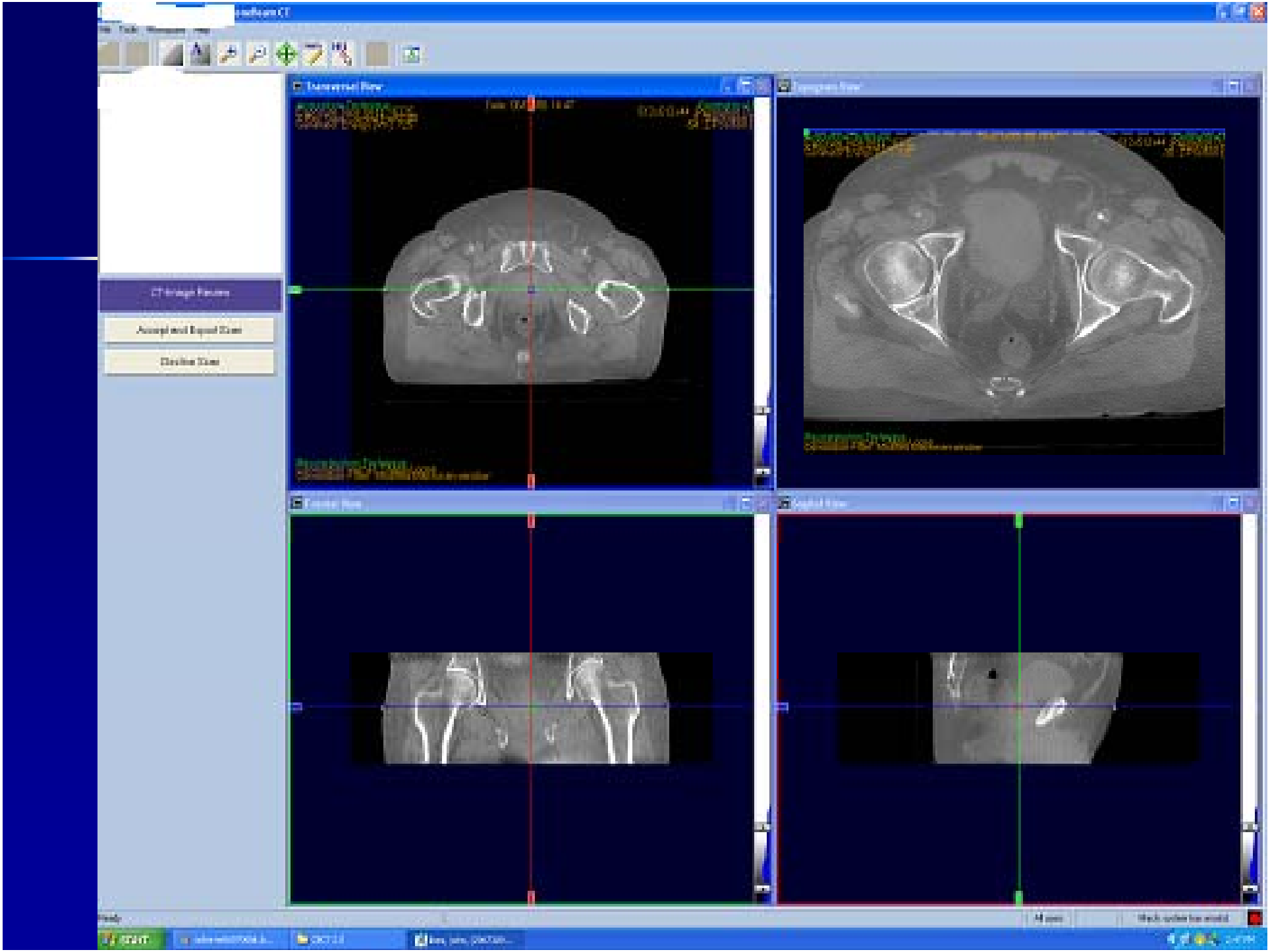


3D/3D Match

SIM CT

CBCT

Shift data


Accept and Export Data
Decline Data


3D / 3D Match
TARGET
ACTUAL
SHIFT
Include
Reset Shift
Apply Shift
All units in cm and degrees
Done

Modes of CBCT Acquisitions

- (A) Full Fan: detector centered 30x40, reconstructed FOV of 24 cm in diameter, 15 cm in C-C extent

- (B) Half Fan: detector shifted by 14.8 cm, FOV=45 cm diameter, 14 cm cm c-c extent

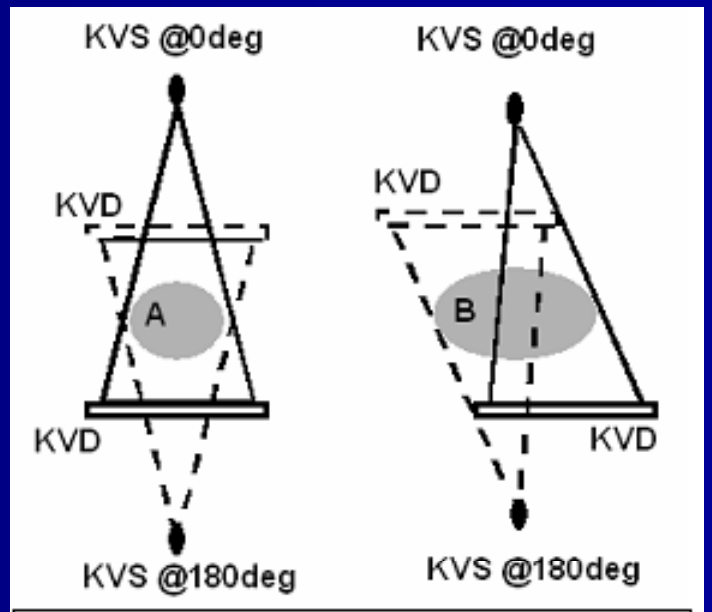
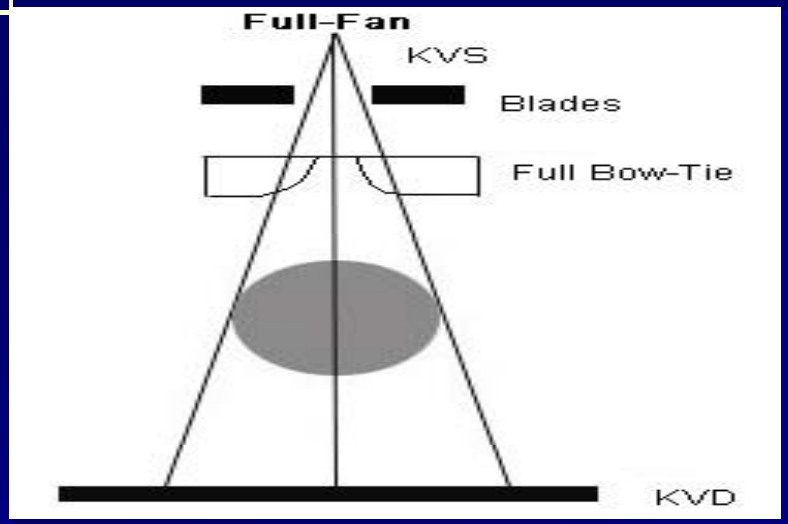
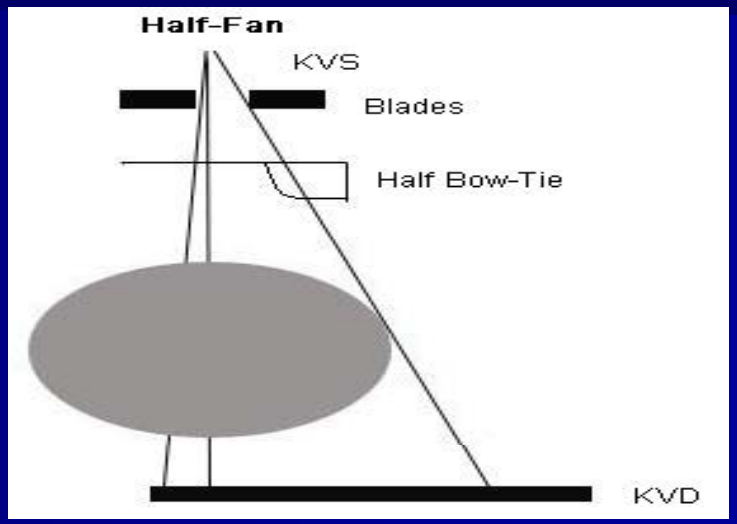
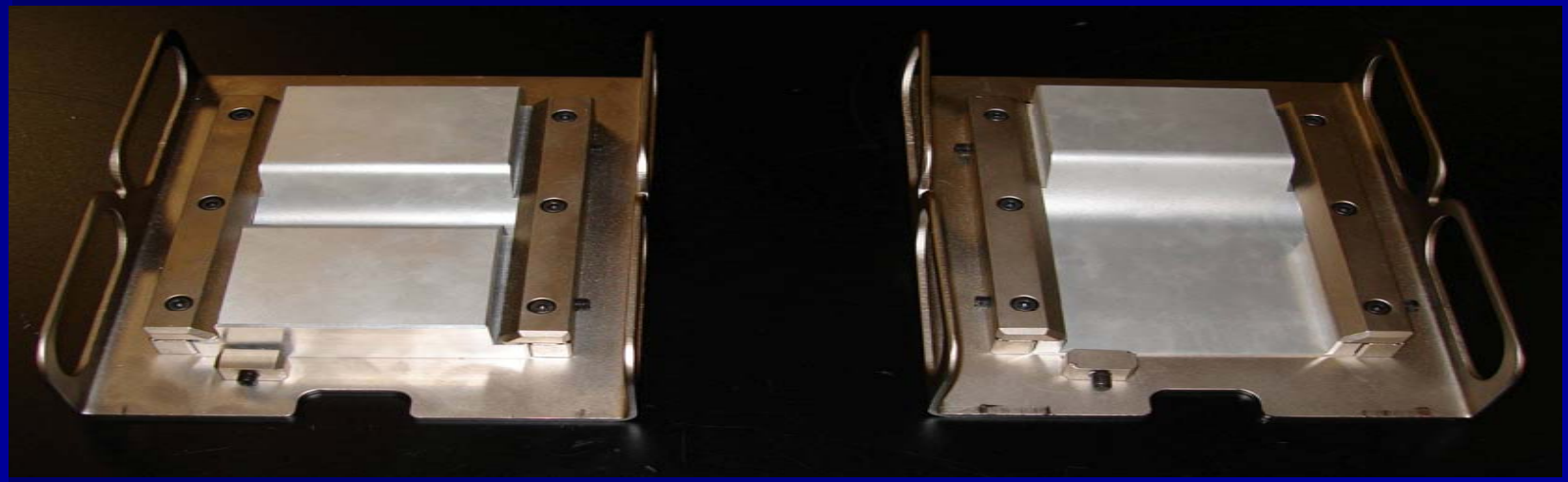


Figure 2 Full-fan mode for a small site, A, and half-fan mode for a large site, B.

Acquisition Modes and Bow-Tie Filters

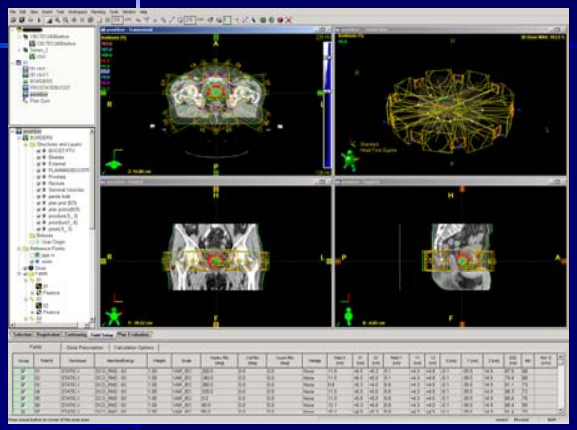




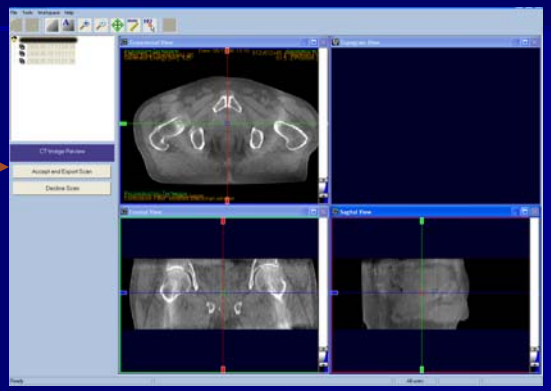


Clinical Protocol for Prostate Cancer

Treatment Planning

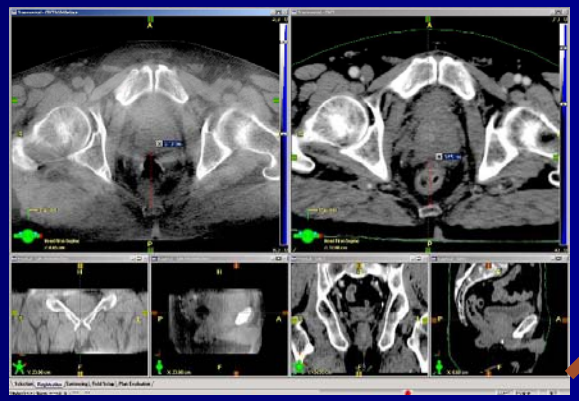


CBCT

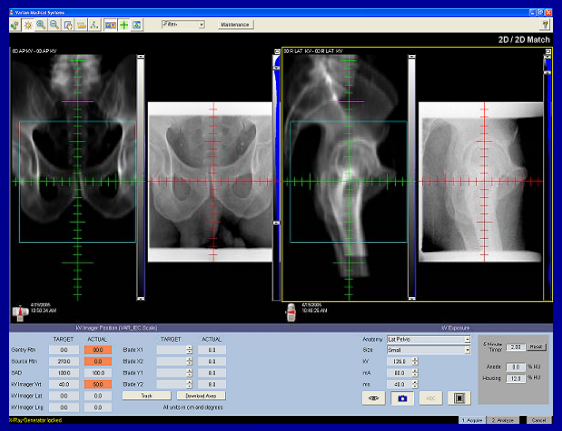


Treatment

SIM CT Scan

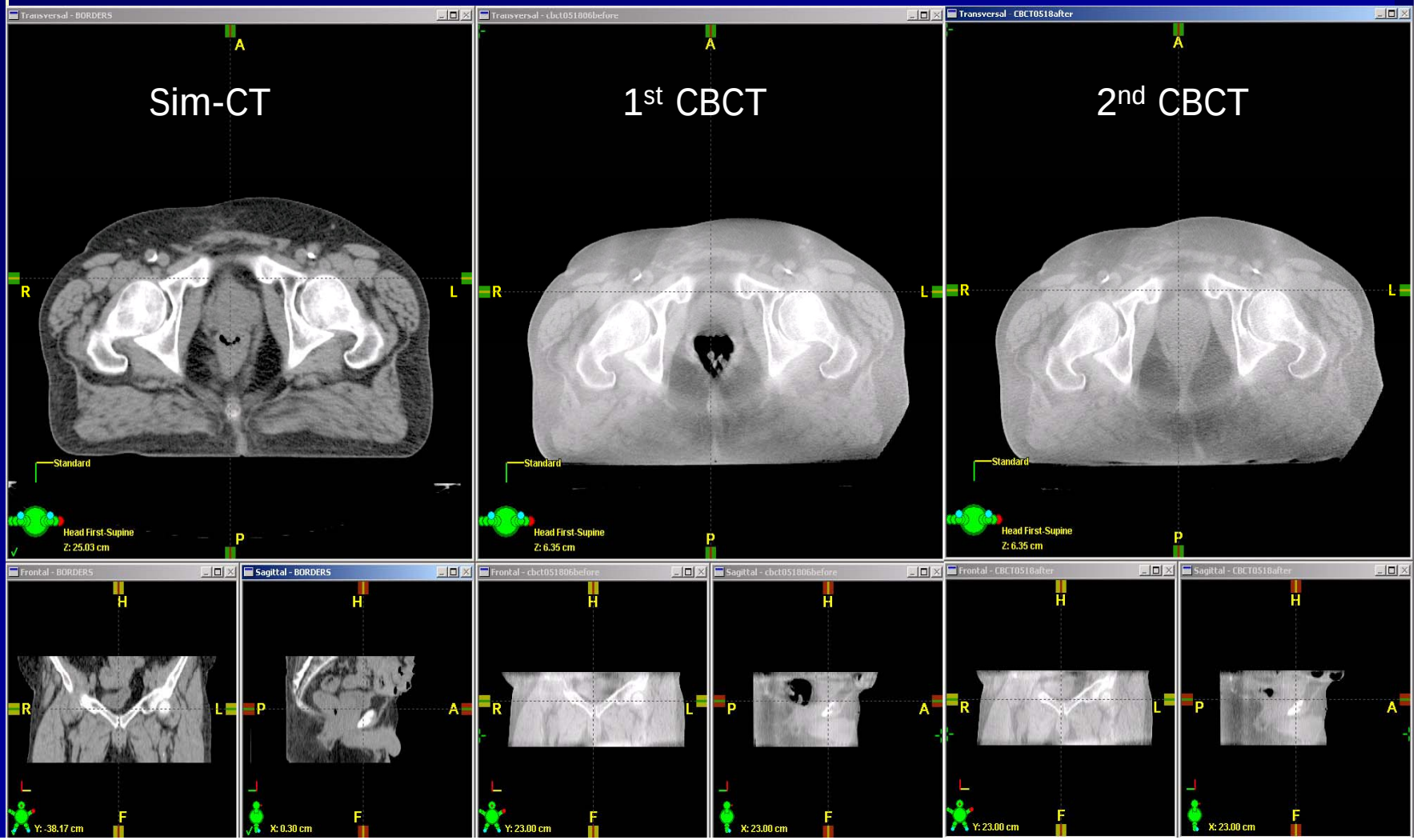


CBCT-SIMCT



Patient Setup

CBCT for Patient Setup



CBCT for Patient Setup

Sim- CT | 1st CBCT | 2nd CBCT

What about dose from CBCT

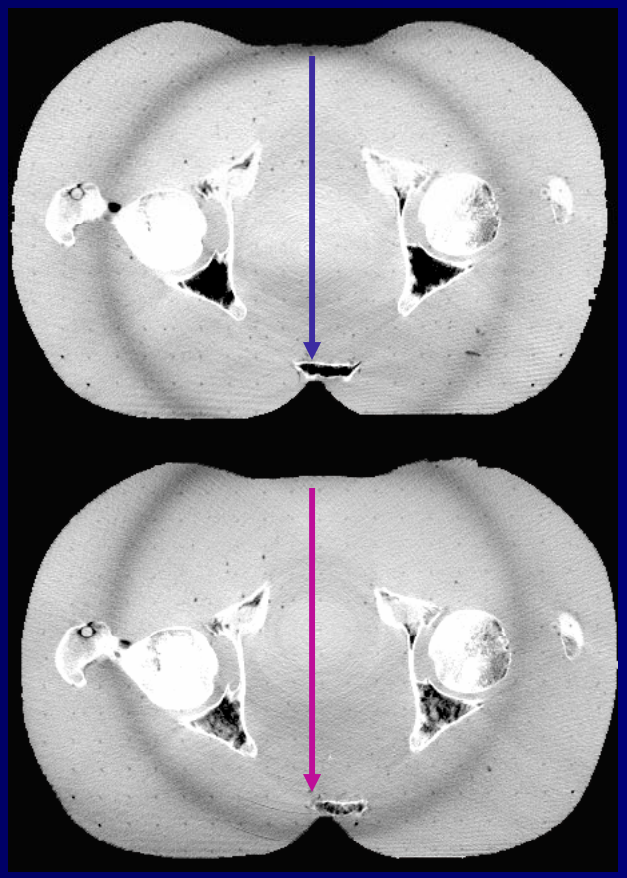
- 42 fractions for prostate treatment
- It is essential to quantify the dose from daily CBCT
- Our work is to measure dose from CBCT

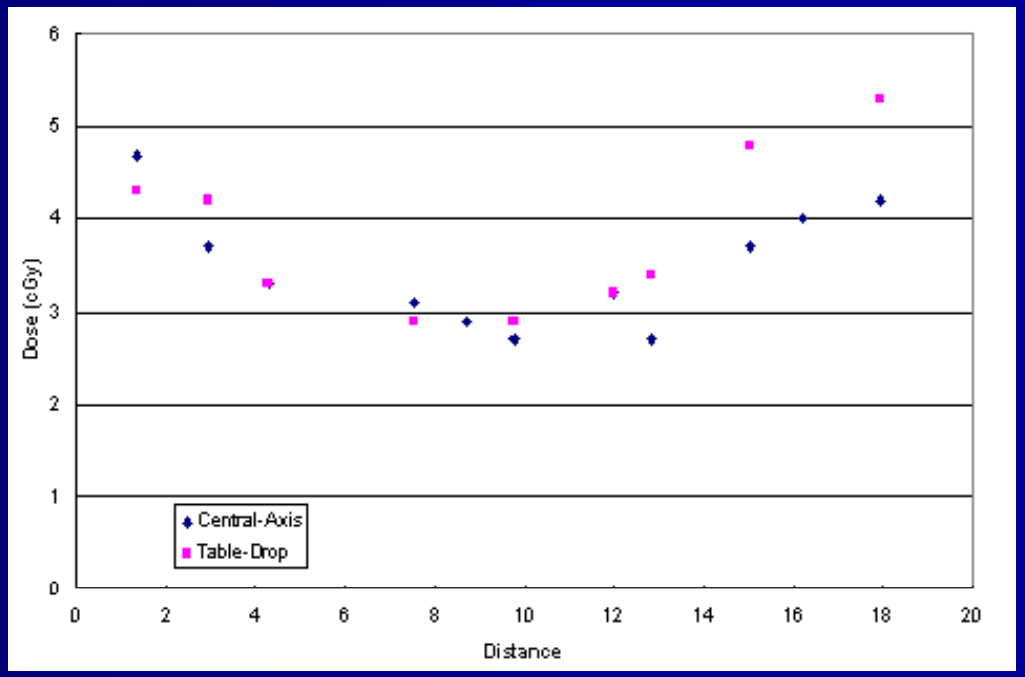
Accepted for Oral Presentation at the 49th AAPM annual Meeting Orlando, FL

Dose Measurement for CBCT

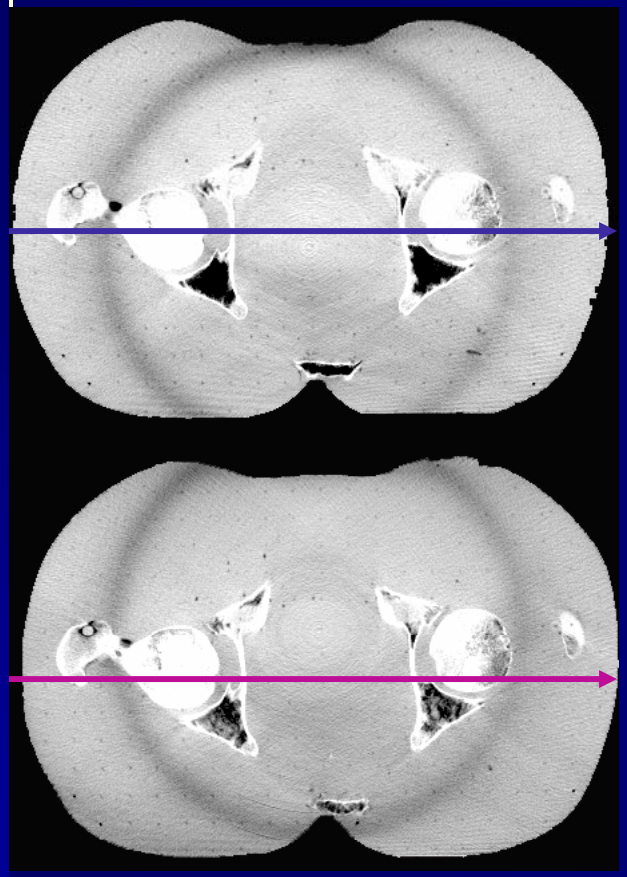
- Surface and body dose for Rando pelvic phantom and IMRT QA phantom.
- In-vivo skin dose of prostate cancer patients acquiring CBCT using TLDs
- Data from TG-61 Protocol

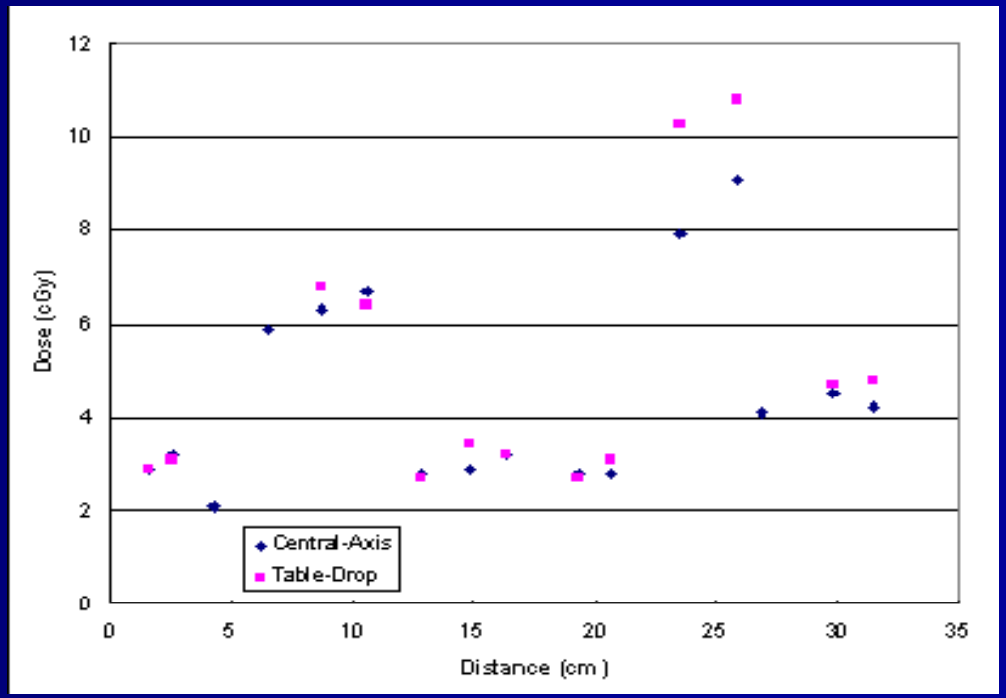
Phantom dose distribution – AP



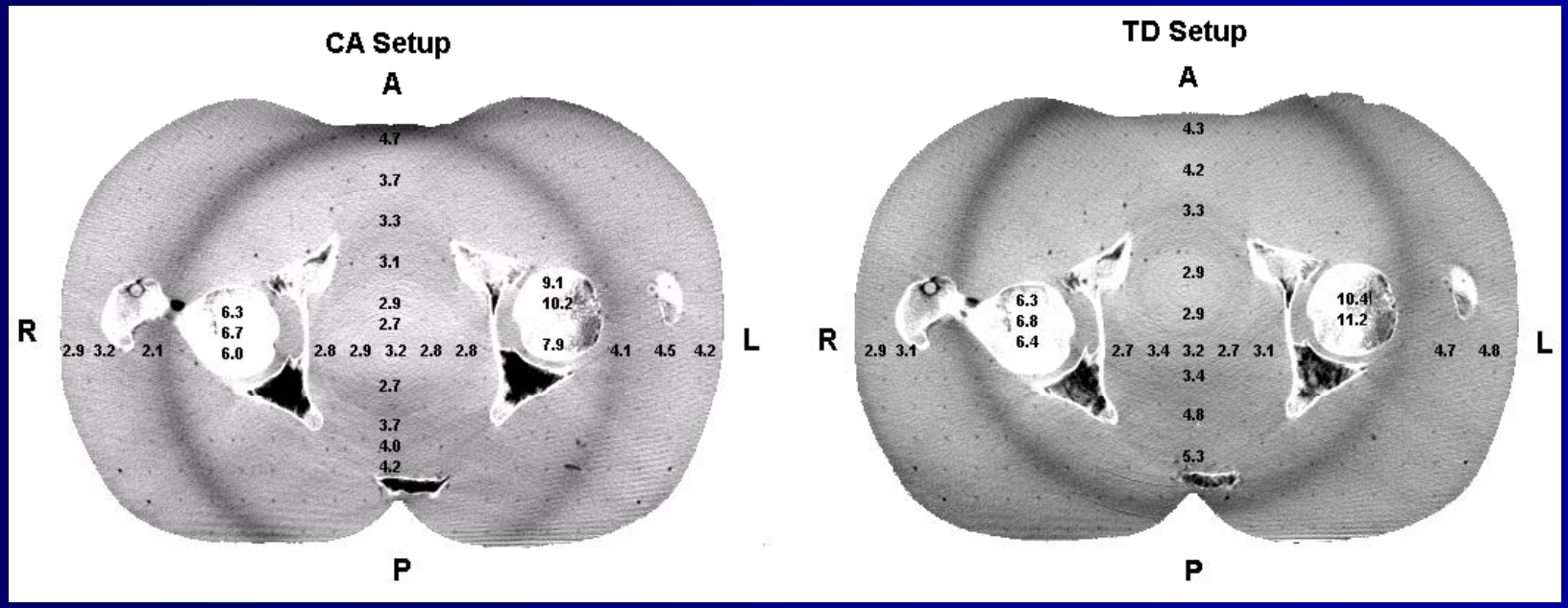


Phantom dose distribution – RL





Phantom Dose Distribution



Discussion

Lt Lat dose is always higher than Rt Lat dose

The reason is that KVS always starts from patient's left and ends at patient's left

There is overlapping for last 10 acquisition and gantry rotation gets slower at the end but dose rate (i.e., pulse rate) keeps the same

Discussion

- Daily CBCT provides better patient setup but it increases skin and body dose. The dose can range from 150 – 250 cGy for skin and 130– 180 cGy for body during the 42 daily fractions delivered for IMRT prostate patients.
- Should we consider the CBCT dose as treatment dose ?

HU Verification

The accuracy of Hounsfield Units (HU) in CBCT not only affect the accuracy of image matching for patient setup, but also the accuracy of actual dose delivered to patient for two reasons:

(a) the accuracy of delineating the structures in CBCT and

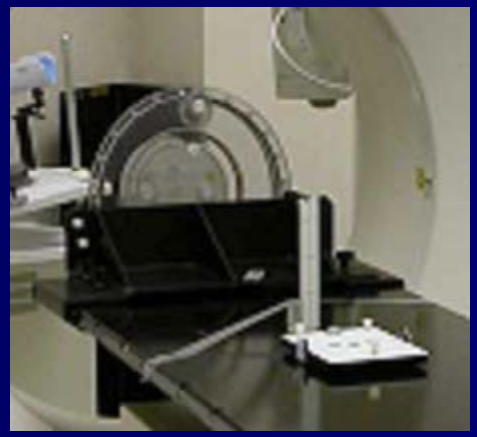
(b) the accuracy of inhomgeneous dose calculation

Accepted for the 49th AAPM Annual Meeting 2006 Orlando, FL

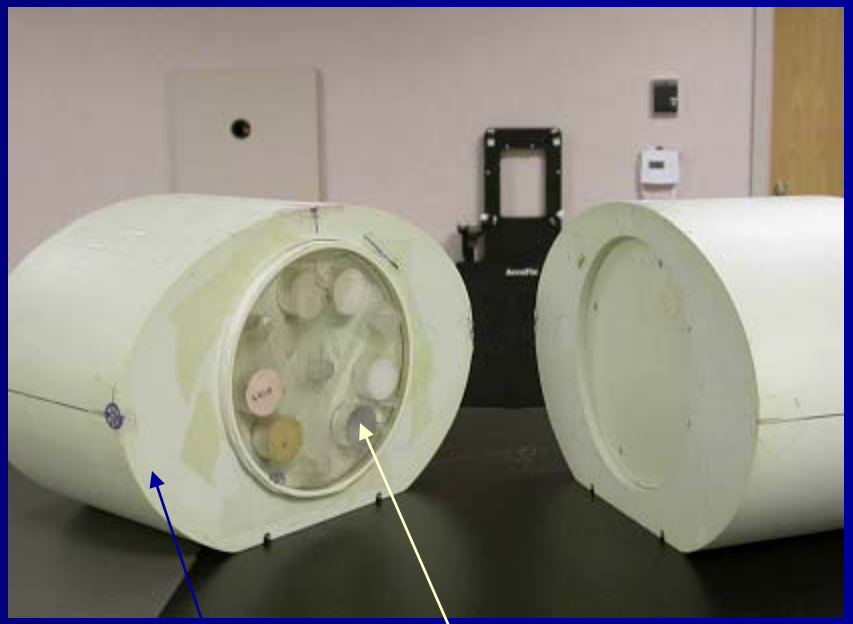
To evaluate the HU accuracy of Varian's CBCT in Half-Fan mode (half bowtie) and its effect to the accuracy of inhomogenous calculation for dosimetric verification of body sites

Phantoms

IMRT QA Phantom
(fixed view)

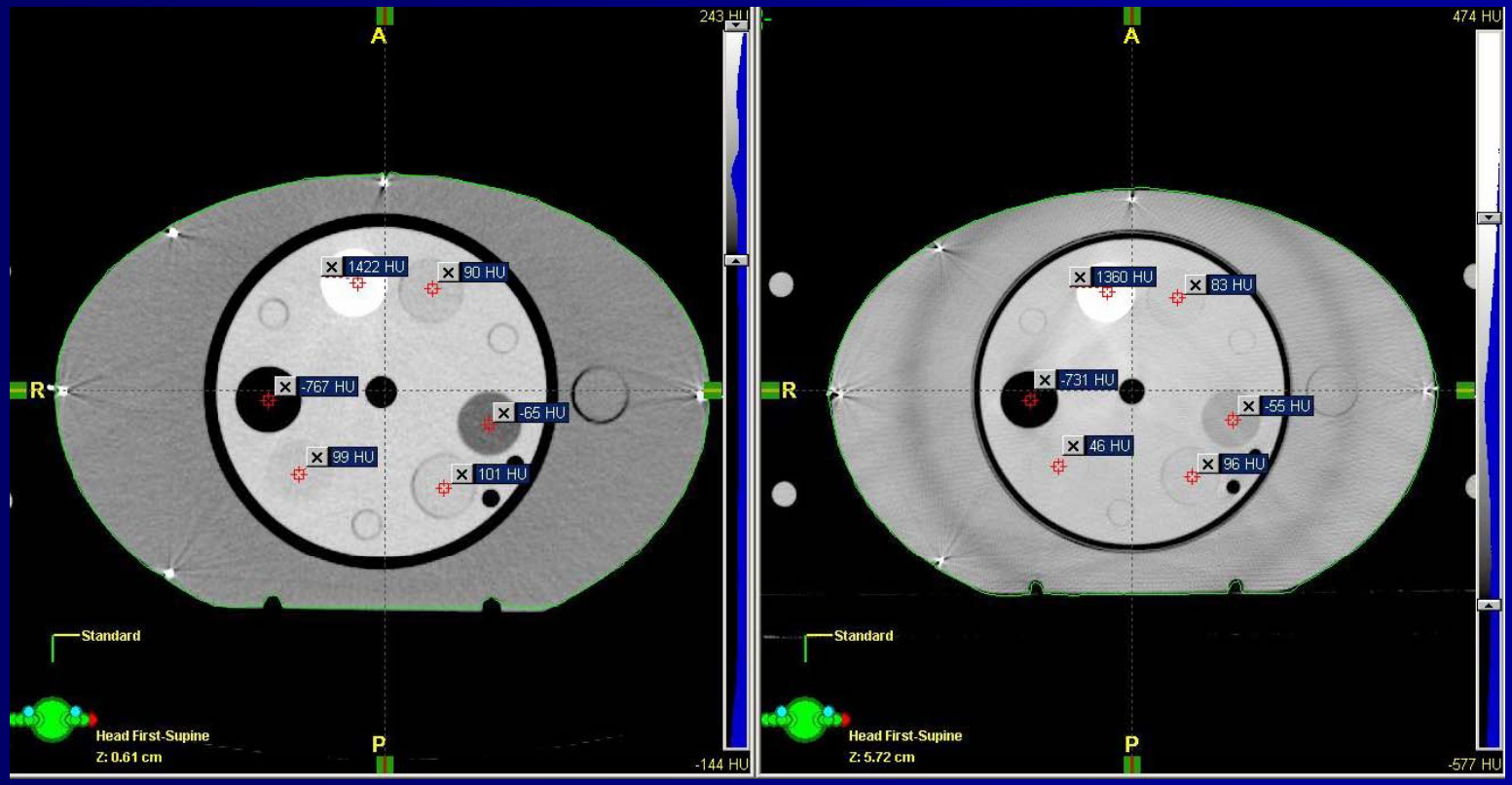


Sim-CT Morning QA phantom

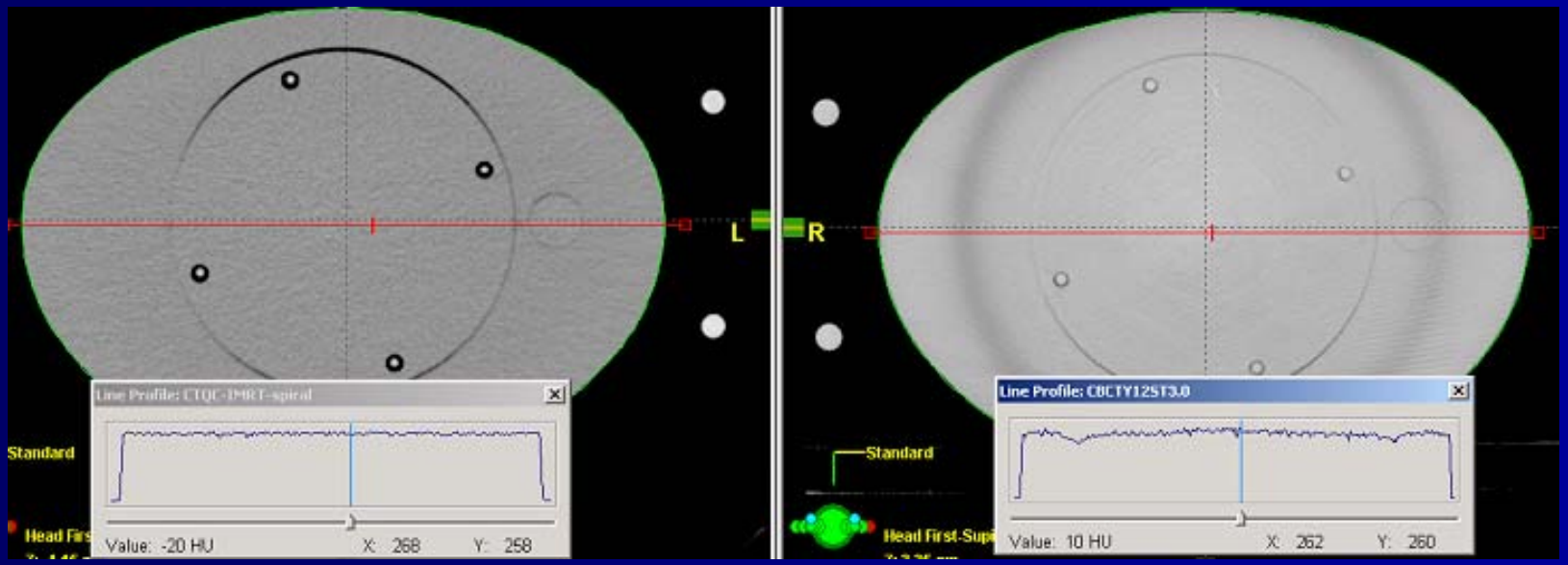


IMRT QA + CTQC phantom
(open view)

The measured HU for each insert in the combined phantom



Demonstration of HU profiles for beam hardening



Sim CT

CBCT

The HU between CBCT and Sim-CT

- The average HU difference between CBCT and SIM-CT is within 20.
- The standard deviation of HU in CBCT is 2 times higher than that in Sim-CT.
- Due to higher beam hardening effect in CBCT, the HU at phantom center is 20 higher than that at edges.

With inhomgeneity correction- Phantom Study

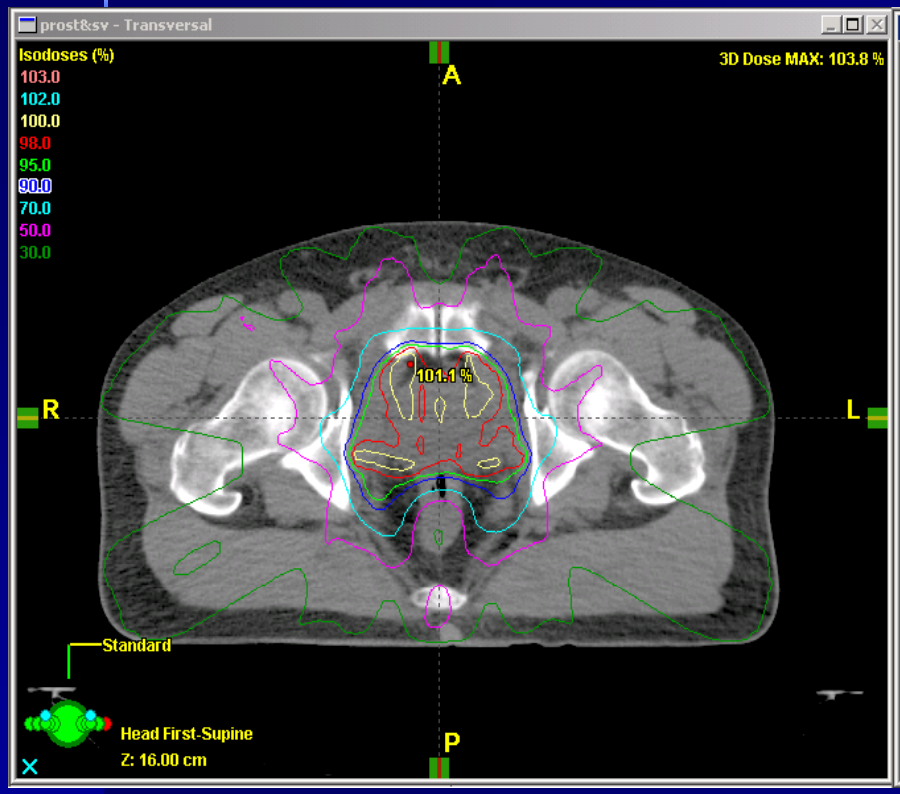
- The DVH difference is from the HU difference alone
- The min dose, max dose, mean dose etc. generally agrees to ~3%

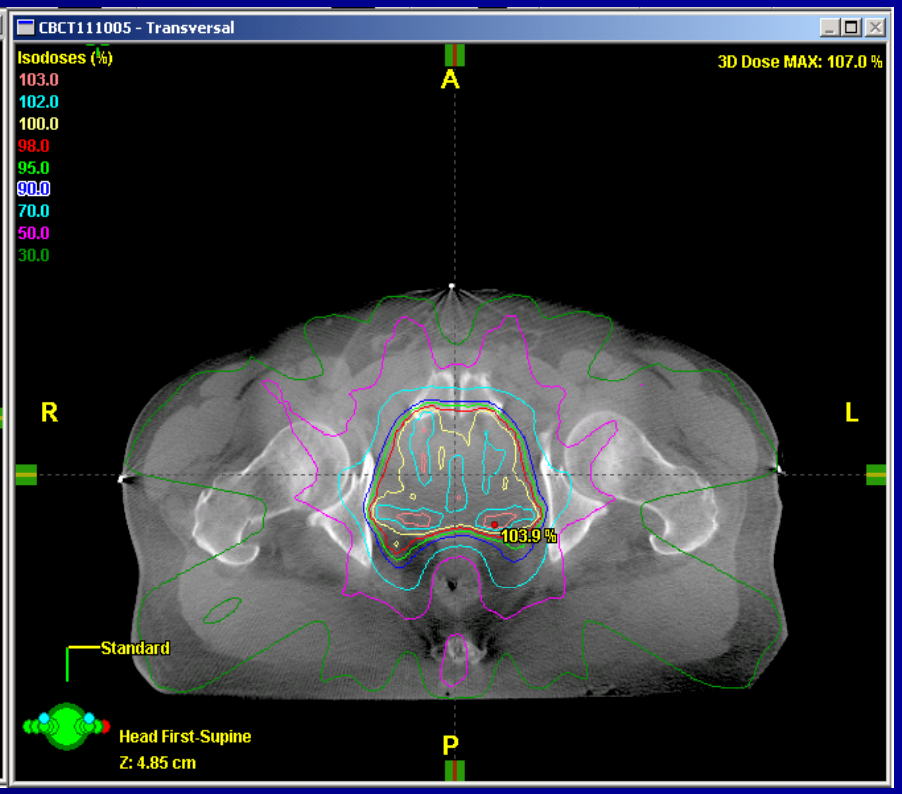
Dose statistics for the 9-beam IMRT plan

For IMRT plans, the dosimetric difference with inhomogeneity correction is also relatively small

The minimum dose, maximum dose, means dose and median dose for any structure agrees generally within ~2-5%

Dose distribution comparison of original Sim-CT plan with a CBCT plan of 0.22cm average SSD difference, dose is 4.4% higher at reference point.





Prostate-Margin Reduction?

1st Prize Winner of the Residents MSTRO Competition 2006

Favorable Risk Prostate Cancer

- 78 Gy, usually prescribed to the 95% isodose line, to the prostate and proximal 1 cm seminal vesicles using an IMRT technique.

- PTV consists of CTV + 10 mm expansion except 6 mm posteriorly

Zelefsky et al. 1999

- 50 patients, 4 CT scans each

Comparison of treatment uncertainties for the posterior border of the prostate and seminal vesicles, before and after correction of systematic error for both organ displacement and set-up error. 1 SD refers to one standard deviation

	Prostate posterior border		Seminal vesicles posterior border	
	Before correction	After correction	Before correction	After correction
1 SD organ displacement (mm)	3.8	2	6.3	4.1
1 SD setup error (mm)	2.3	1.9	2.3	1.9
1 SD total uncertainty (mm)	4.4	3.4[a]	6.7	4.9[a]
Mean organ displacement (mm)	− 1.4	0.0	− 0.8	0.0
93% Confidence limit margin (mm)	8.1	5.1	10.9	7.4
Coverage probability for 6 mm margin (%)	85	96	78	89

[a] Includes 2 mm correction uncertainty.

Patients

- Five patients with localized prostate cancer were simulated with CT sim and treated to the prostate and proximal 1 cm seminal vesicles to a dose of 78 Gy.
- Educated regarding empty bladder and empty rectum.

Imaging

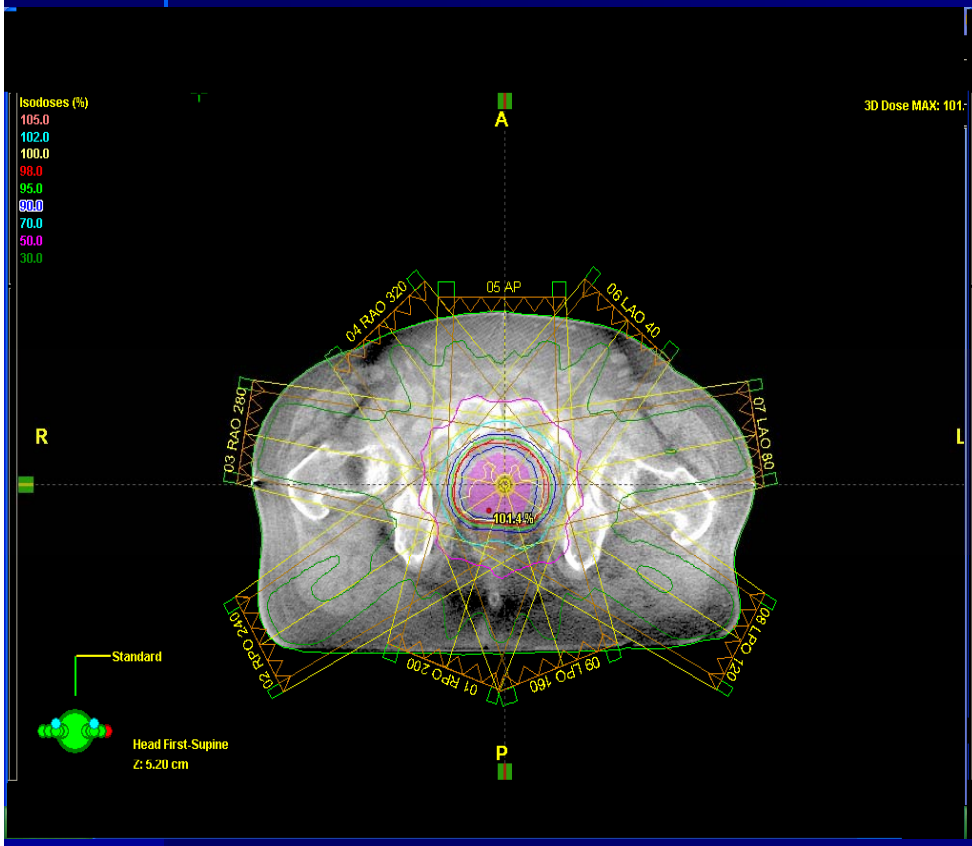
- Prior to 30 treatment fractions, a cone beam CT was obtained followed by an orthogonal set of radiographs using the OBI.
- Patients were shifted according to image registration between radiographs and simulation DRRs. (Patients were initially aligned to skin marks)

Plans

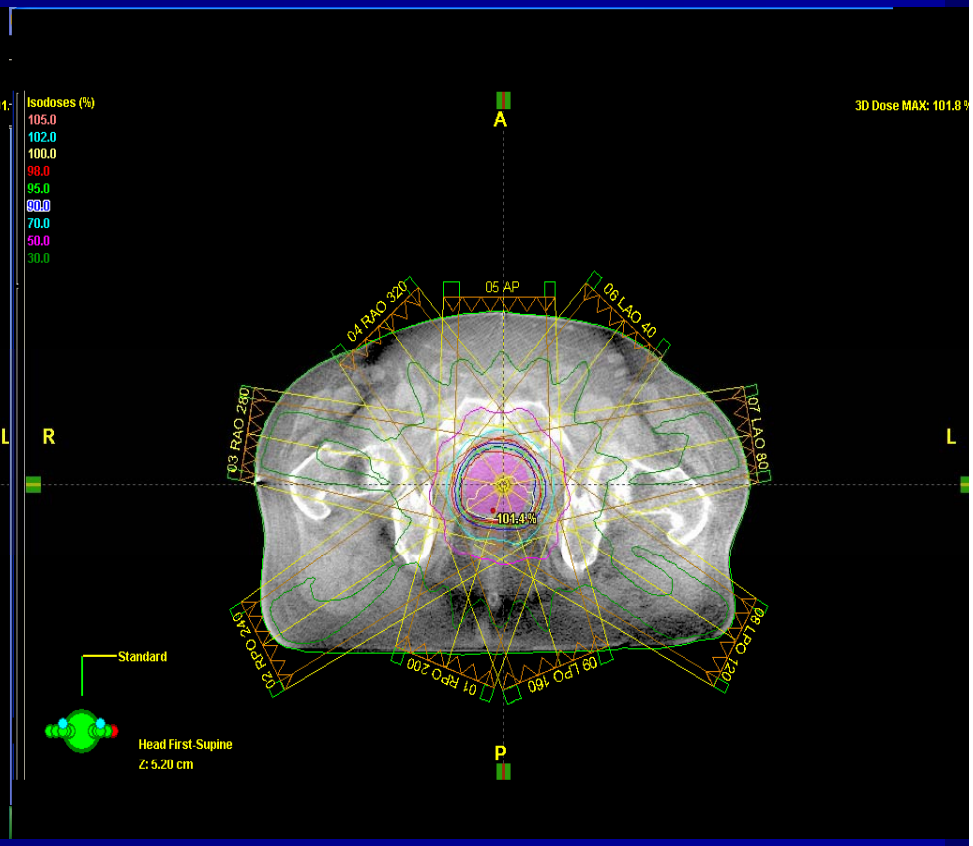
- All organs of interest were contoured on each cone beam CT scan.
- Using each cone beam CT scan, a coplanar nine field IMRT plan was created using the patient's treatment position coordinates as isocenter.
- Two separate plans were created one with a 10/6 mm expansion and a 5/3 mm expansion

Treatment Plans

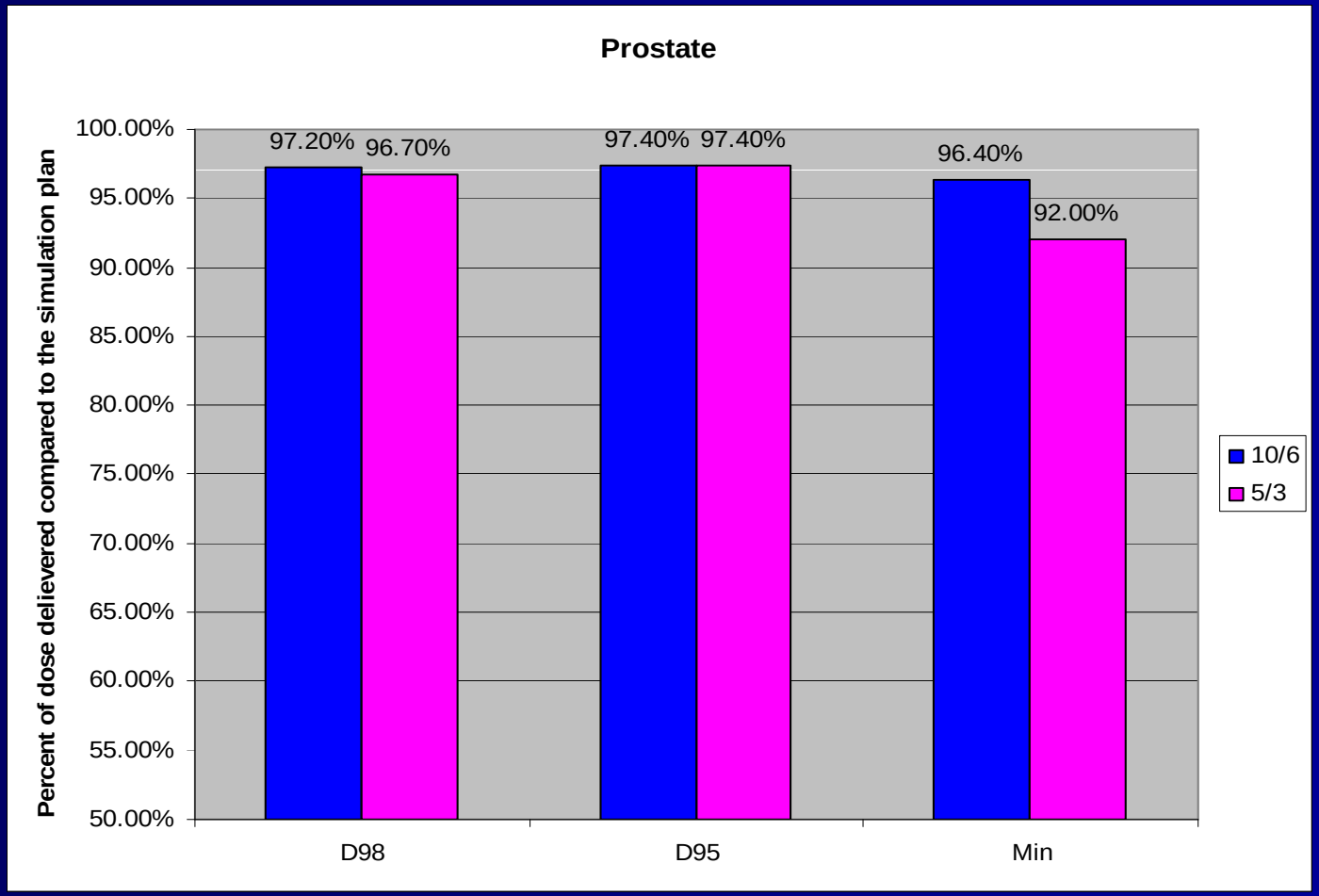
10/6 Plan



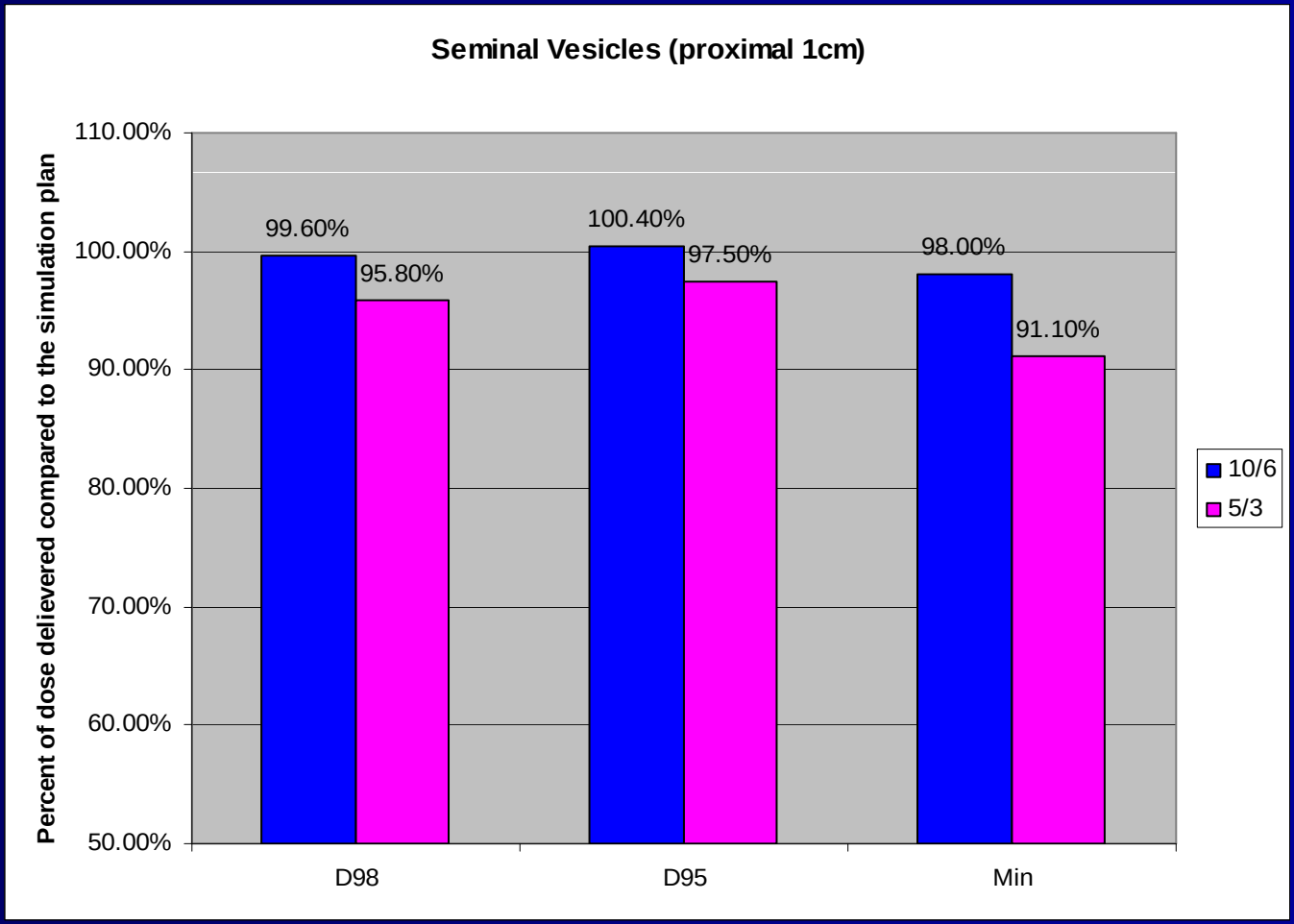
5/3 Plan



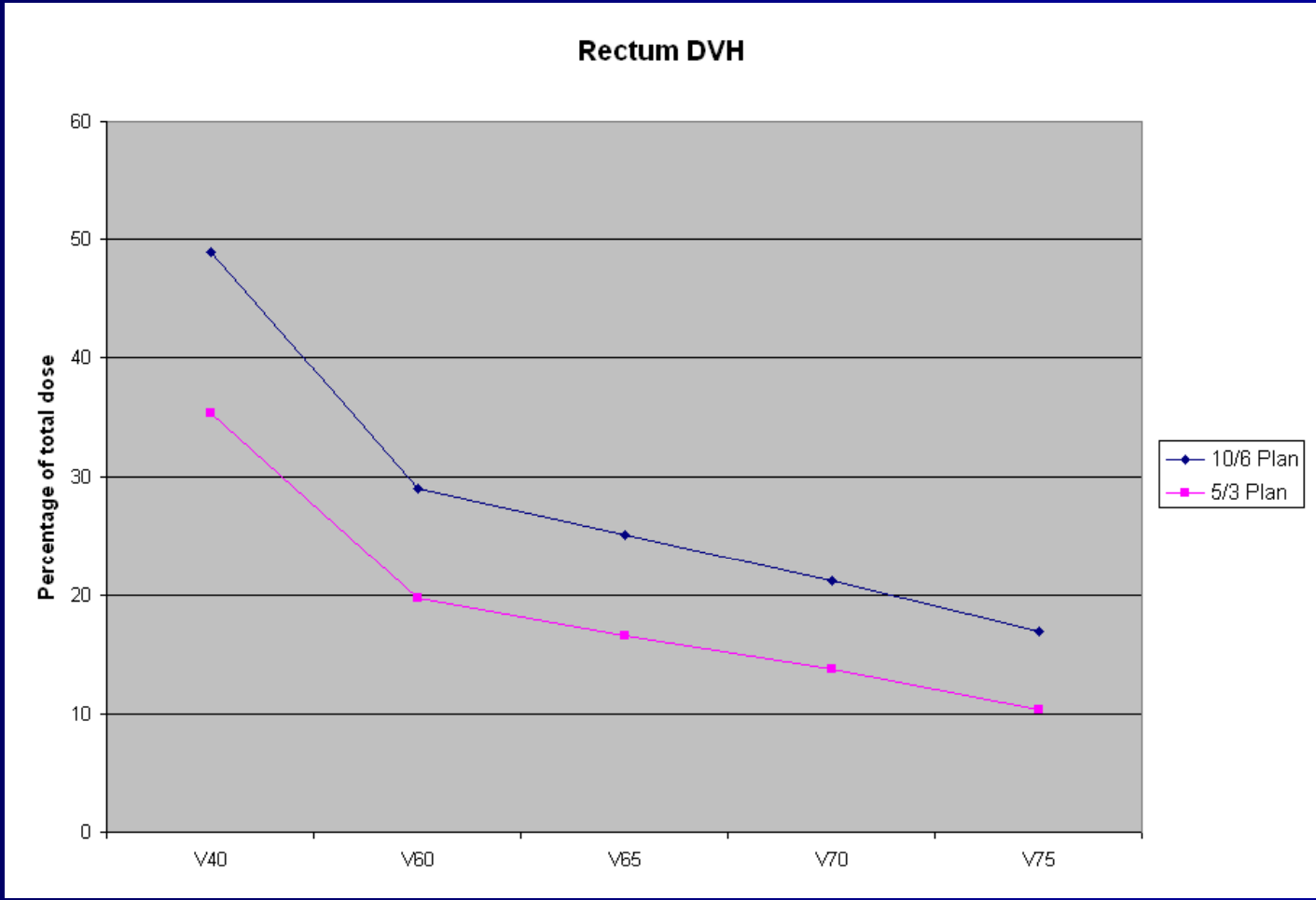
Data Analysis



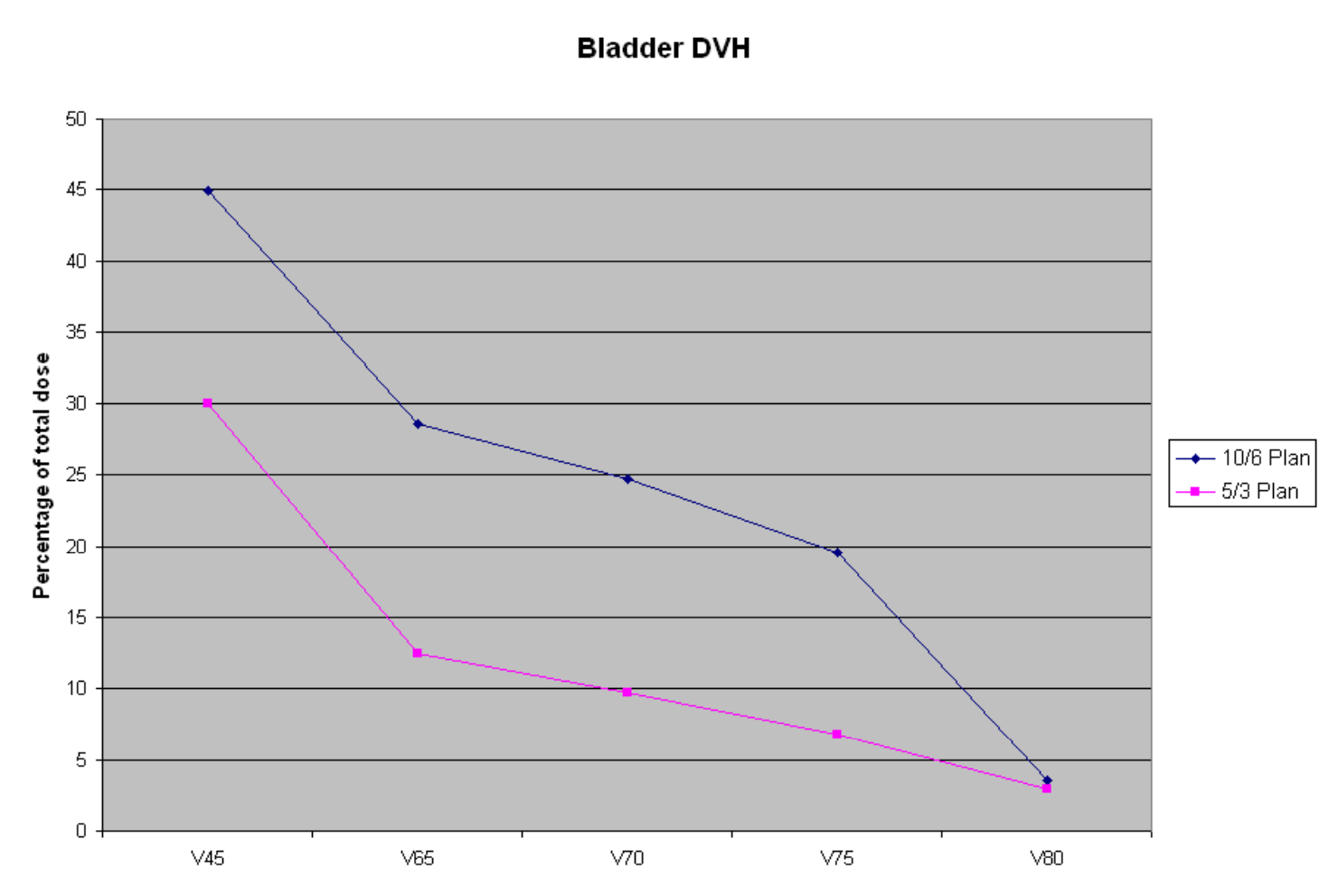
Data Analysis



Data Analysis



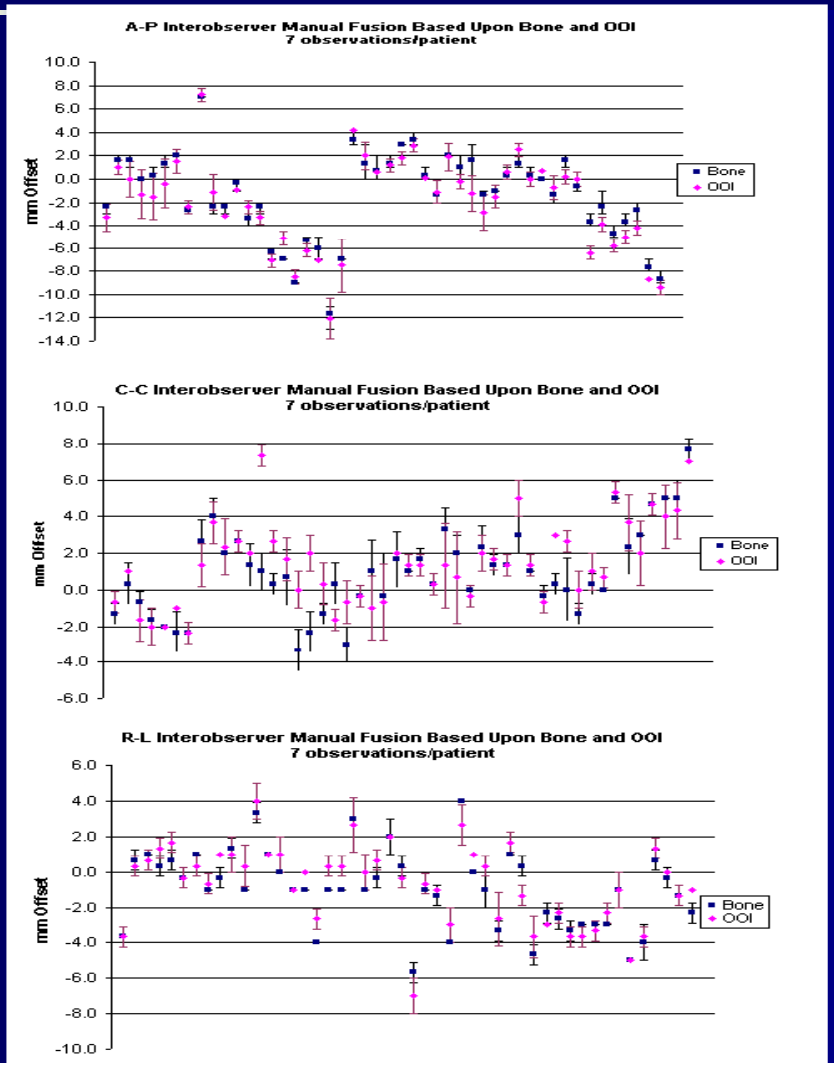
Data Analysis

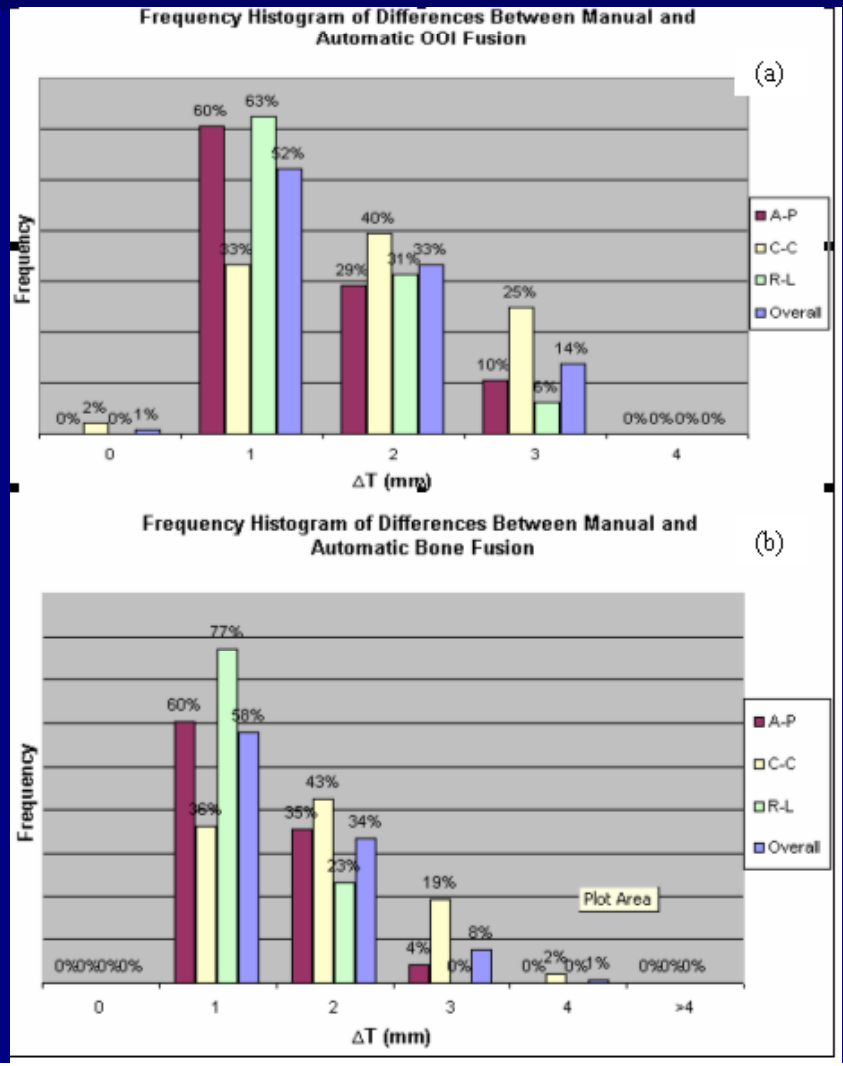


Margin Reduction-Results

- Our data indicates a 5/3 margin results in a fairly close dose distribution to the 10/6 margin.
- 5/3 margin reduced high dose bladder and rectum volumes by 30-50%

Interobserver Variability Study
3D/3D Image Fusion





Interobserver Variability Study-Results

- Mean shifts (mm) and SDs were
  -0.4±4.2 (A-P) 1.4±2.4 (C-C) -0.7±2.3 (R-L)

- Comparing different observers
  69% (C-C), 83% (A-P) 100% (R-L)

Of the observations fall within 1 mm SD for ROI matching

69% (C-C) 75% (A-P) 90% (R-L)

of the observations fall within 1 mm SD for OOI matching

Averages (mm) and SDs of the differences between Manual and Automatic Fusion

	A-P	C-C	R-L
ROI	0.5±1.0	1.3±1.0	0.5±0.6
OOI	0.6±1.0	0.3±1.5	0.8±0.7

Intensity based 3D/3D Fusion

- ROI
  - Rectangular and irregular mask ROI
- Similarity Measure
  - MI – Mutual Information
  - NCC – Normalize Cross Correlation
  - EOD – Entropy of Difference
  - GC – Gradient Correlation
  - GD – Gradient Difference
  - PI – Pattern Intensity
  - CR – Correlation Ratio
- Transformation
  - Rigid Body Transformations
    - Translation (3D)
    - Translation (3D) + Table Rotation
    - Translation (3D) + Rotation(3D)
  - Affine Transformations
    - Shearing + Rotation + Translation
    - Scaling + Shearing + Rotation + Translation
- Optimization
  - Downhill Simplex

Prostate Localization

- **Pelvic bone matching**
  - A rectangular ROI is defined around pelvic bone (excluding femur bones) on either sim or cbct.
  - Similarity measure MI works very well for bone matching.
  - Typically 100 iterations is enough (less than 5 sec on 3GHz CPU)

- **Prostate matching**
  - An irregular mask ROI is defined around prostate and seminal vesicles on the sim CT.
  - Similarity measure GC works the best from experiments.
  - Typically 100 iterations is enough (less than 5 sec on 3GHz CPU)
  - If the prostate boundary is blurry or if there is prominent rectum gas pockets, registration may fail.

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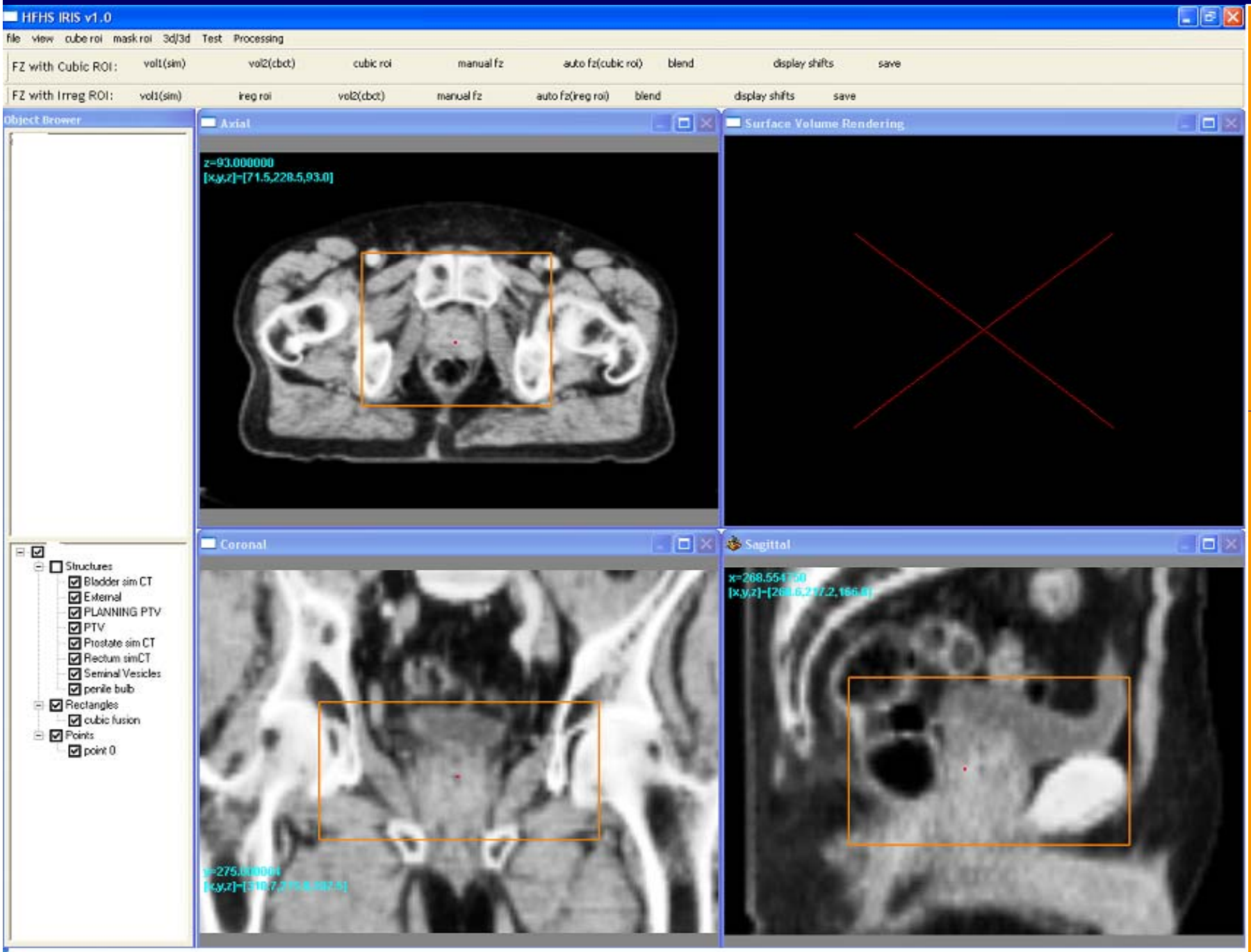
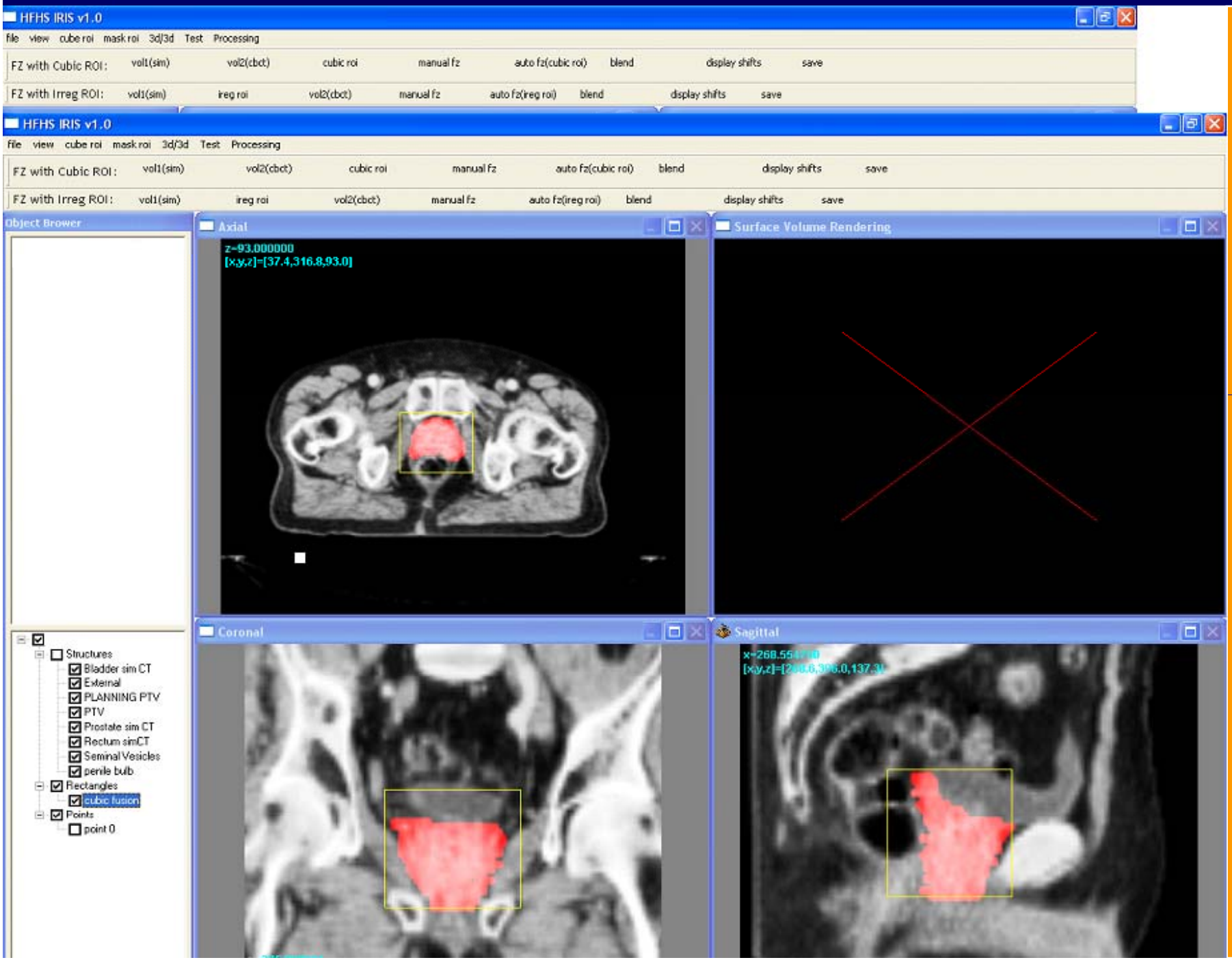
Rectangular ROI



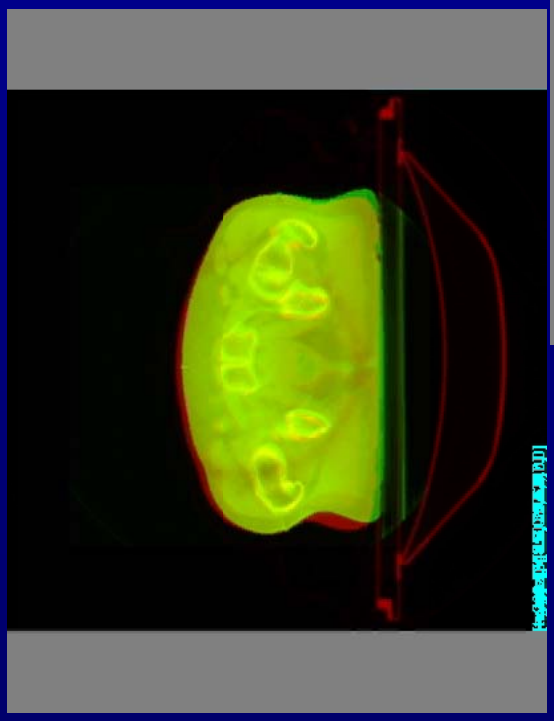
Irregular ROI



Fusion: Uphill Simplx

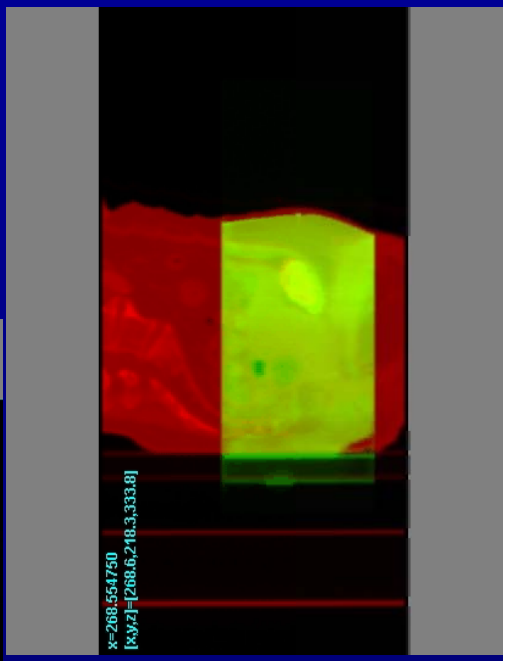
Bone Matching

Click each image to start and stop animation

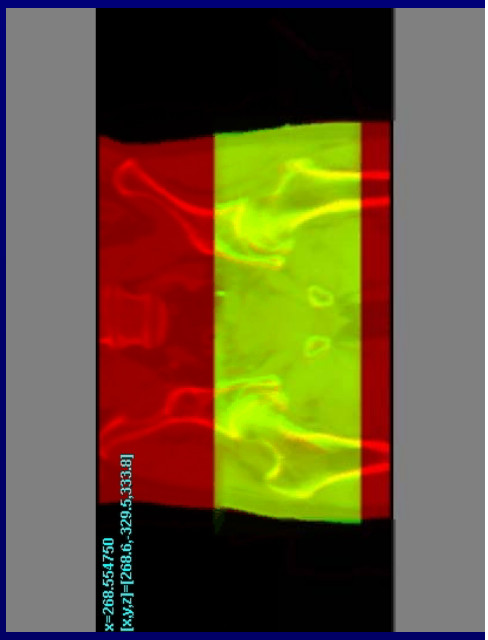


animation

animation

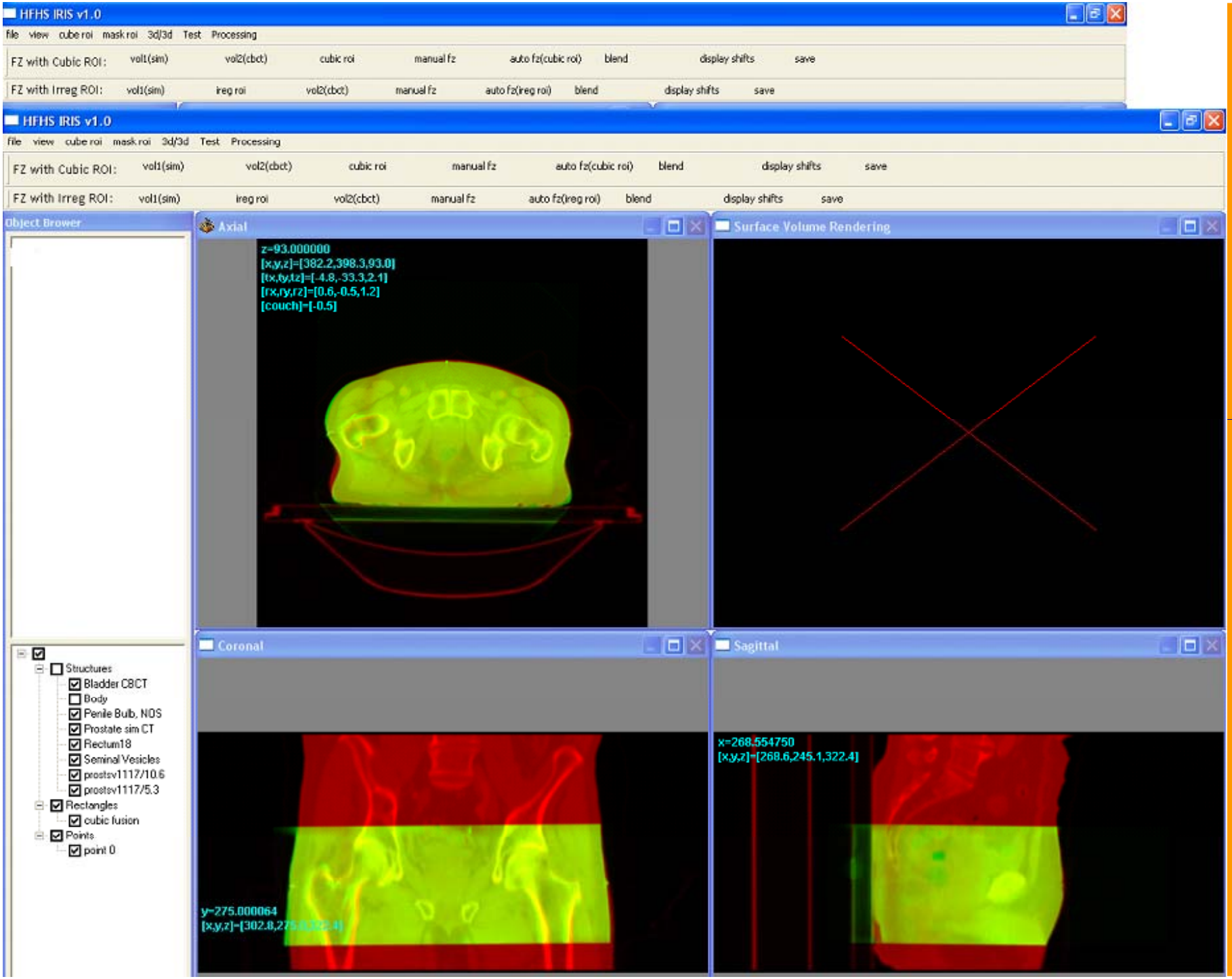


animation



animation

Fusion Verification: Color Channel View



- IS OBI sufficient for Prostate localization?
- OBI and margin reduction?

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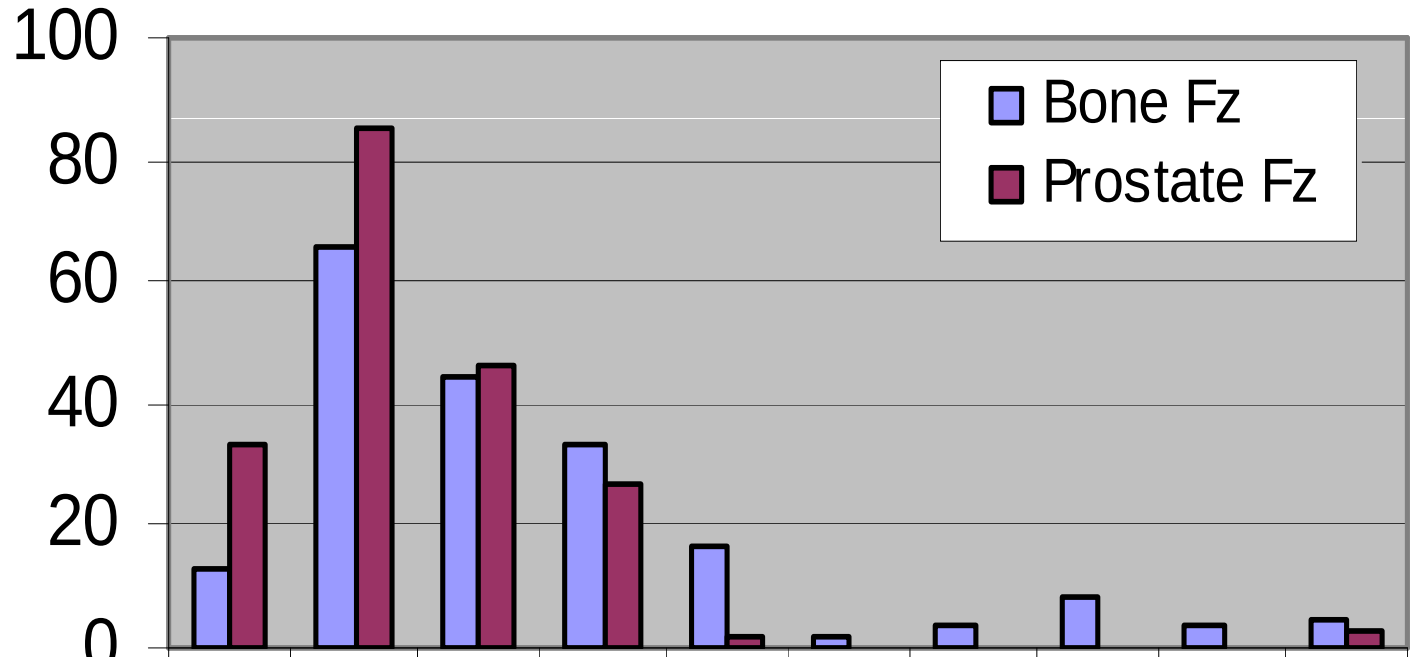
Automatic pelvic bone matching vs. prostate matching



	0~1	1~2	2~3	3~4	4~5	5~6	6~7	7~8	8~9	9~
Bone Fz	13	66	44	33	17	2	4	8	4	5
Prostate Fz	33	85	46	27	2	0	0	0	0	3

Comments on the three failures

- Case 1: I forgot identifying the calcification points by mistake. Registration was successful (visual confirmation)
- Case 2: the patient was large and the prostate boundary was not clear. Registration failed.
- Case 3: there was a rectum gas pocket near the target. Registration failed.


Varian Medical Systems
3D / 3D Match
Transversal - cbct - ImageUShort120 - 6/16/2006 - 4:08 PM
Transversal - cbct
Frontal - cbct - ImageUShort120 - 6/16/2006 - 4:08 PM
Auto Match Control
Progress
Algorithm run succesfully to completion
Start
Reset
Close
Couch Shift (VAR_IEC Scale)

IGRT/OBI QA Procedures

- QA program to maintain and monitor system performance characteristics established at the time of commissioning

- QA Program should include
  1. Safety and functionality of the system
  2. Geometry
  3. Image quality
  4. Database and data transfer integrity

OBI QA- Tools

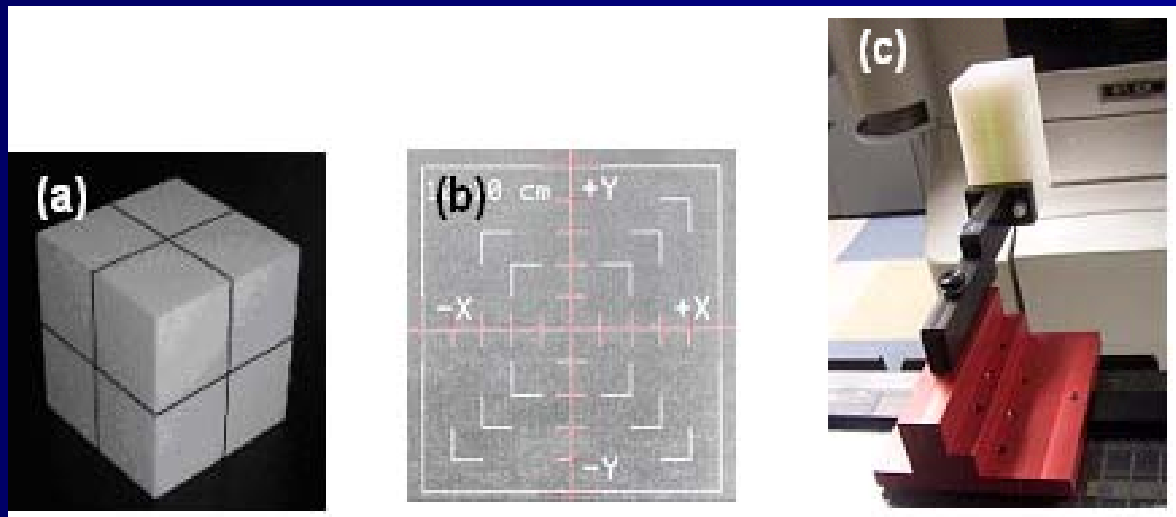


Figure 3 (a) Cube phantom with 1 fiducial marker at the center of the cube), (b) printed circuit board and (c) marker block with 1 fiducial marker at the center and 4 disks inside of the block.

OBI: Daily QA

Daily QA procedure checks the geometric accuracy of the OBI system by performing the following tests:

- Test 1: Tube/detector positioning accuracy
  - Assures that the imagers (MVD &KVS/KVD) isocenter matches the LINAC isocenter
- Test 2: Matching and couch motion accuracy
  - Positional differences detected by the OBI workstation can be reliably transferred to couch motion

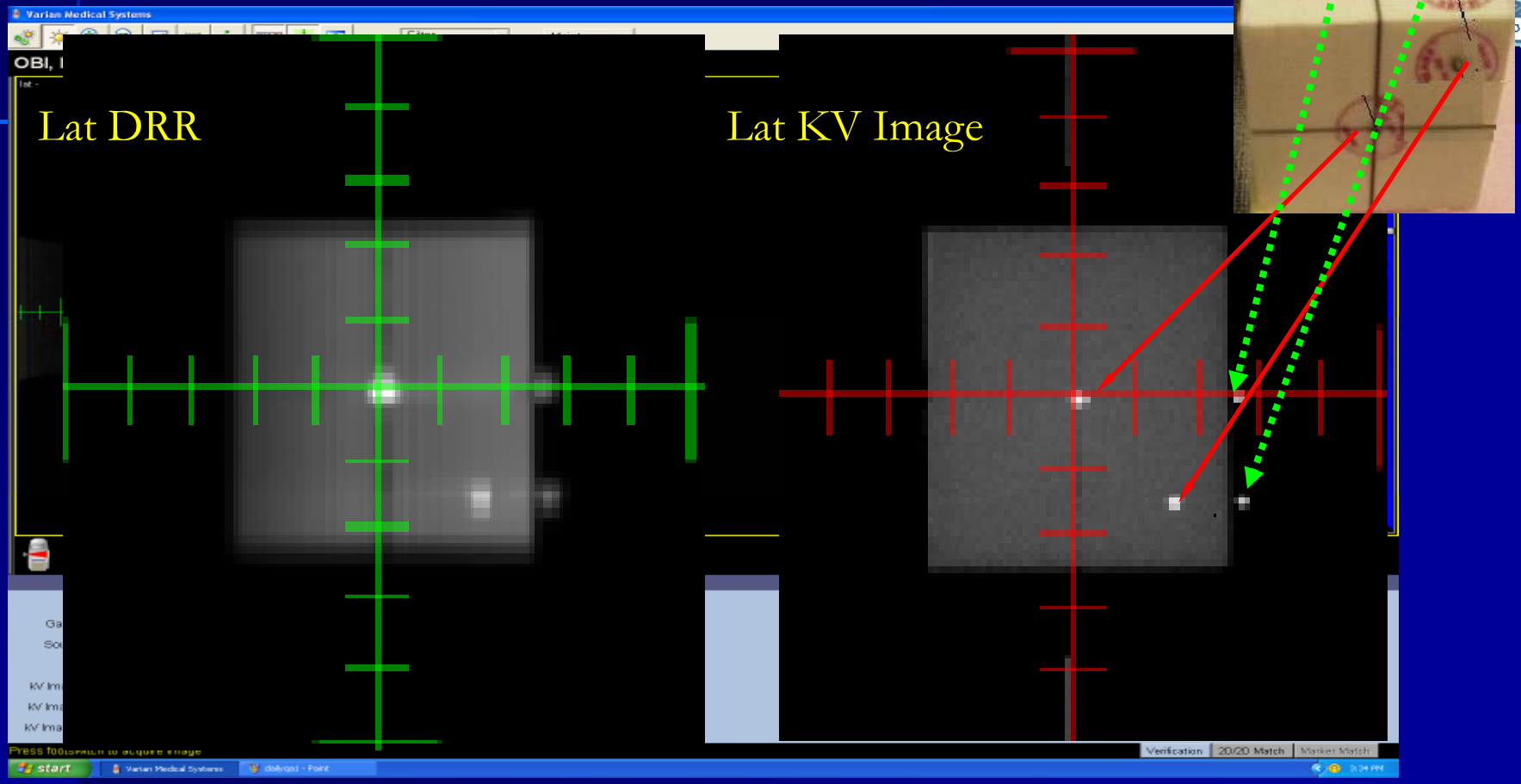
OBI: Daily QA

- The Cube Isocenter Phantom provided by *Varian* was used for this daily QA procedure
- Two sets of 1.5-mm lead shots (bbs) were used to define 2 separate spatial locations (points.)
- In each set, one bb is on the anterior side (AP bb) and the other (Lat bb) is on the lateral side of the phantom
- The first set defines the isocenter (at the phantom center) and the second set defines a point 1.5 cm anterior, inferior, and lateral from the isocenter

OBI: Daily QA

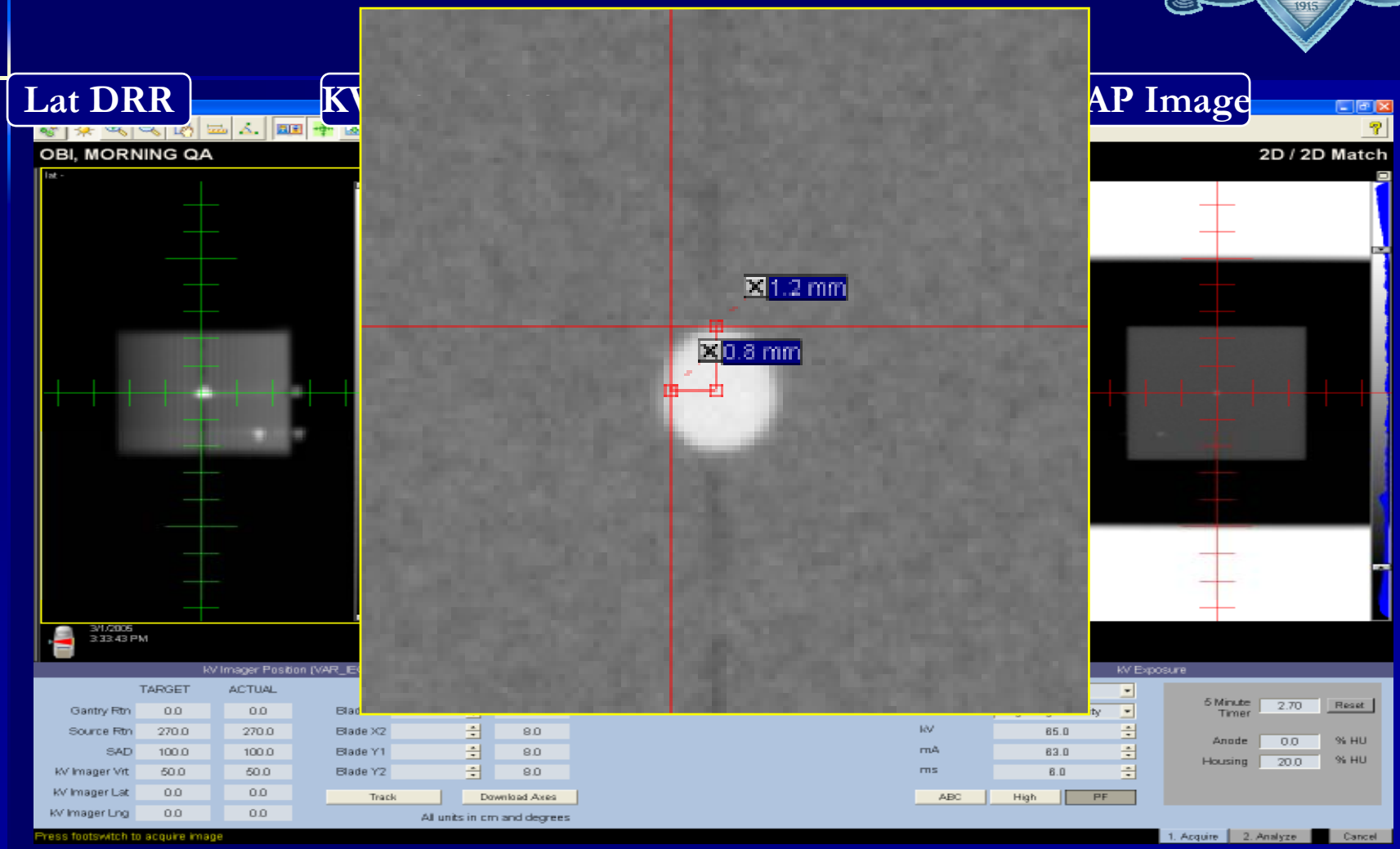
The OBI daily QA procedure starts with setting up the Cube phantom center (central bb set) at the mechanical isocenter of the linac by using the cross hairs projections anteriroly and laterally

OBI: Daily QA



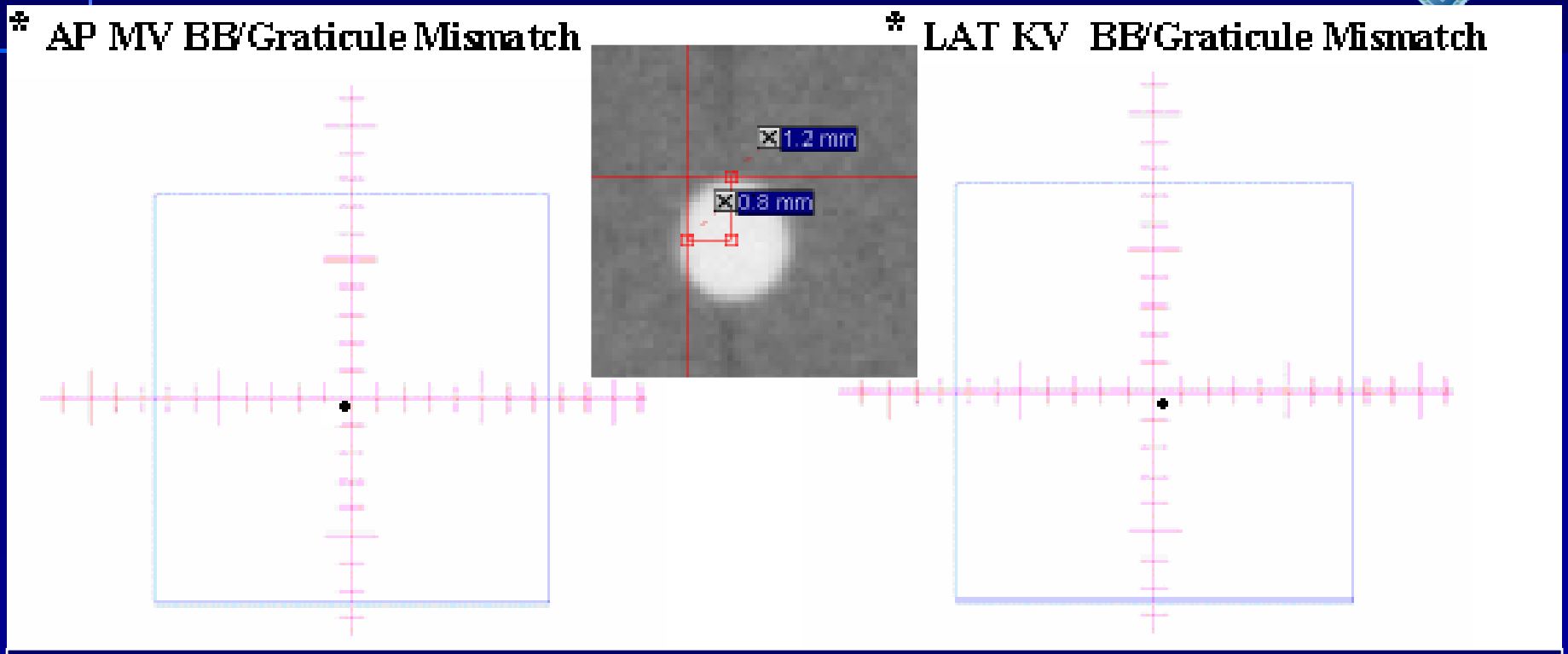
Using the plan created from *Eclipse*, AP MV (or KV) and Lat KV images were acquired *(shown only Lat image)*

OBI: Daily QA-Test 1



The alignment of the central bbs with the digital graticule (representing the imager isocenter) will be checked from both AP and Lat images

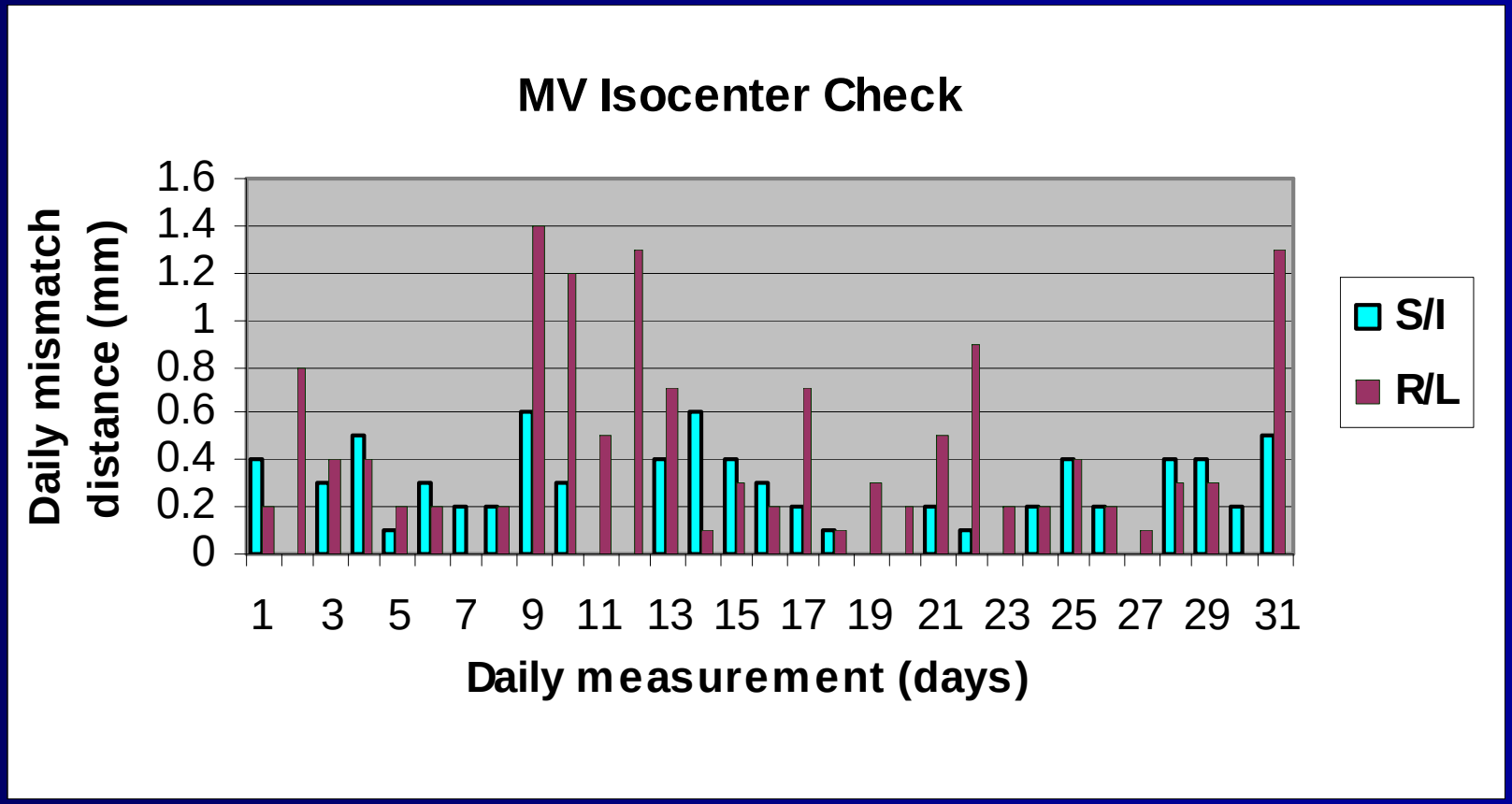
OBI: Daily QA-Test 1



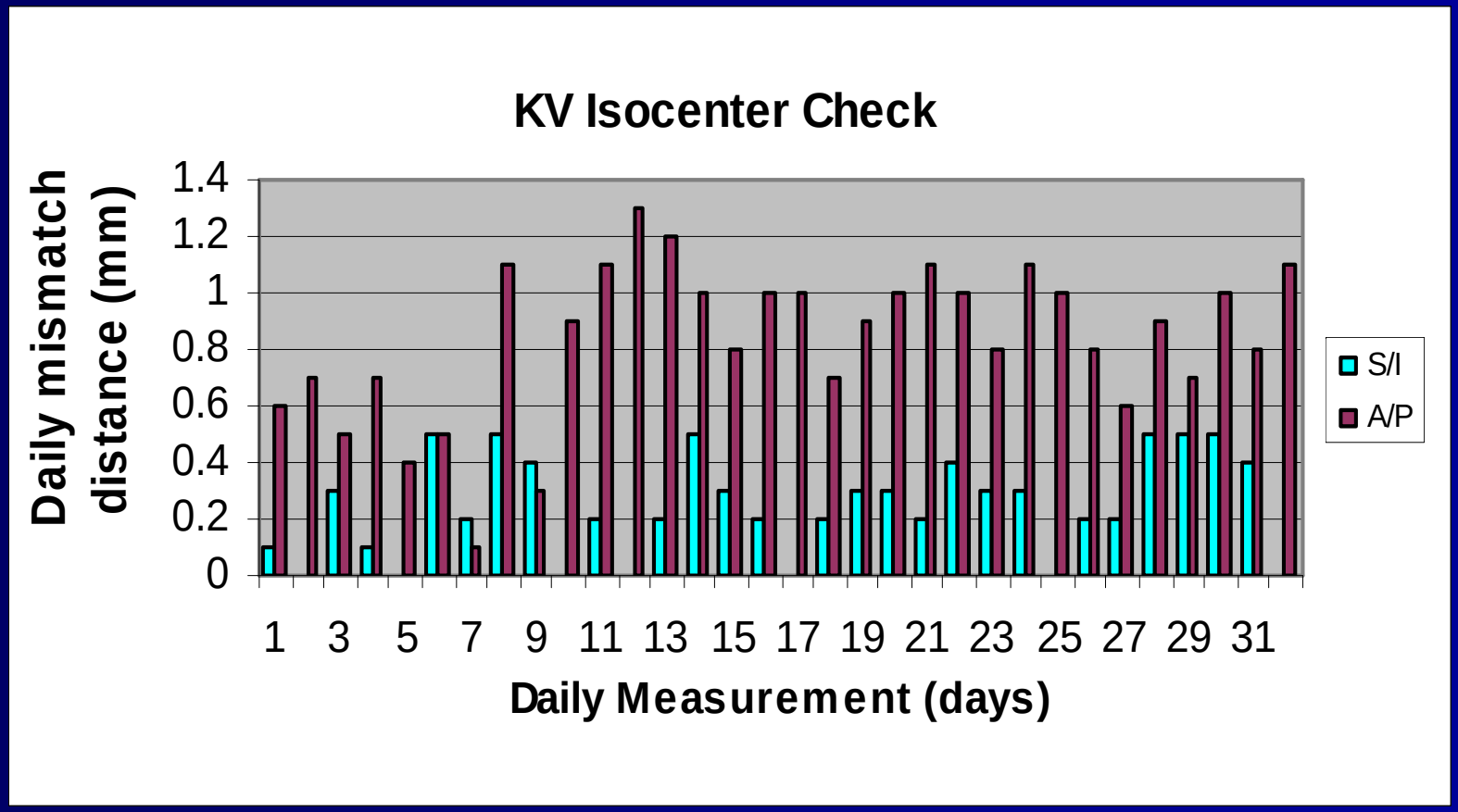
Long: __ mm OK ≤ 1.5 mm	Long: __ mm OK ≤ 1.5 mm
Lat: __ mm OK ≤ 1.5 mm	Vert: __ mm OK ≤ 1.5 mm

3 translational shifts between the center of the graticule and the center of the bbs were measured and tabulated

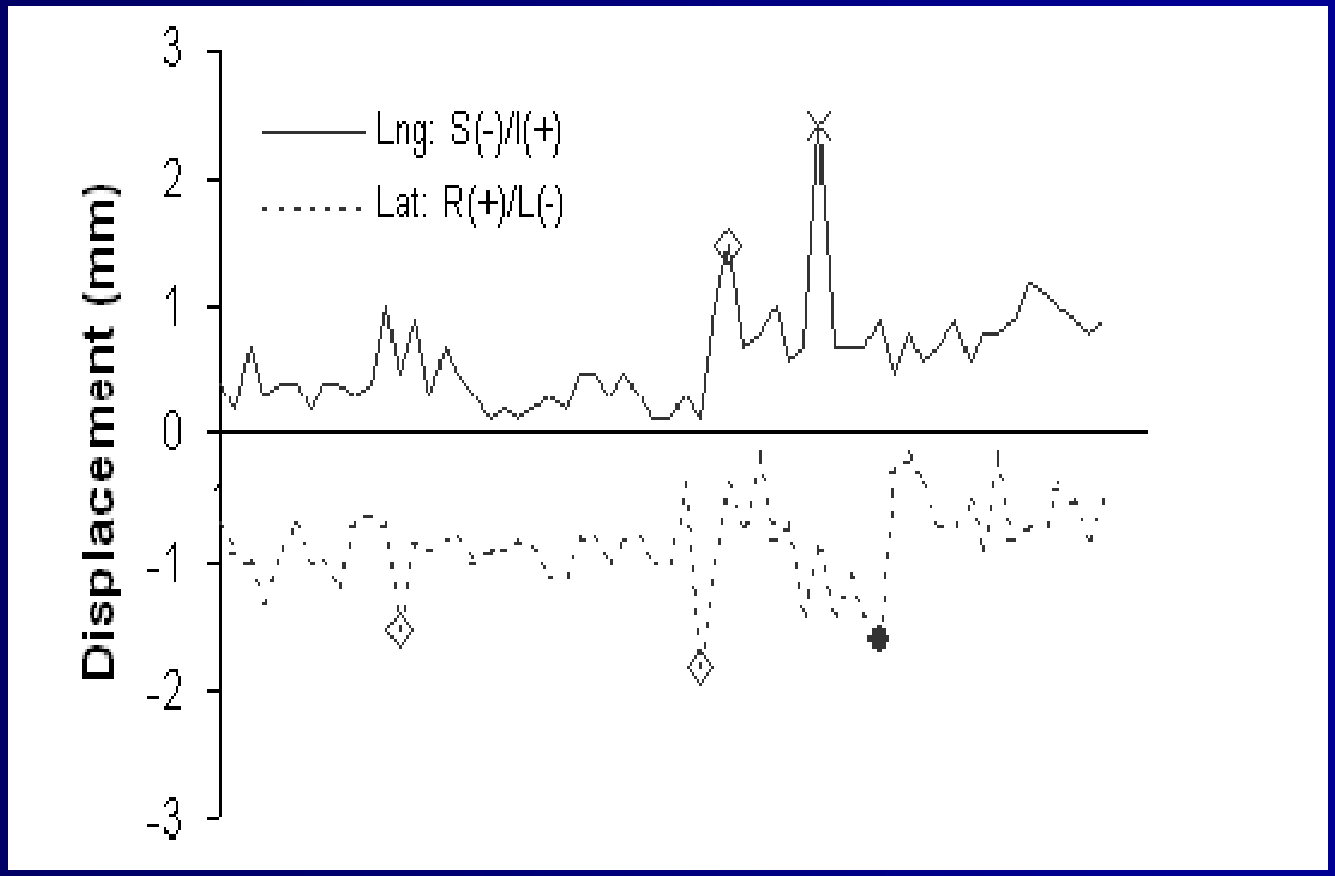
OBI: Daily QA-Test 1



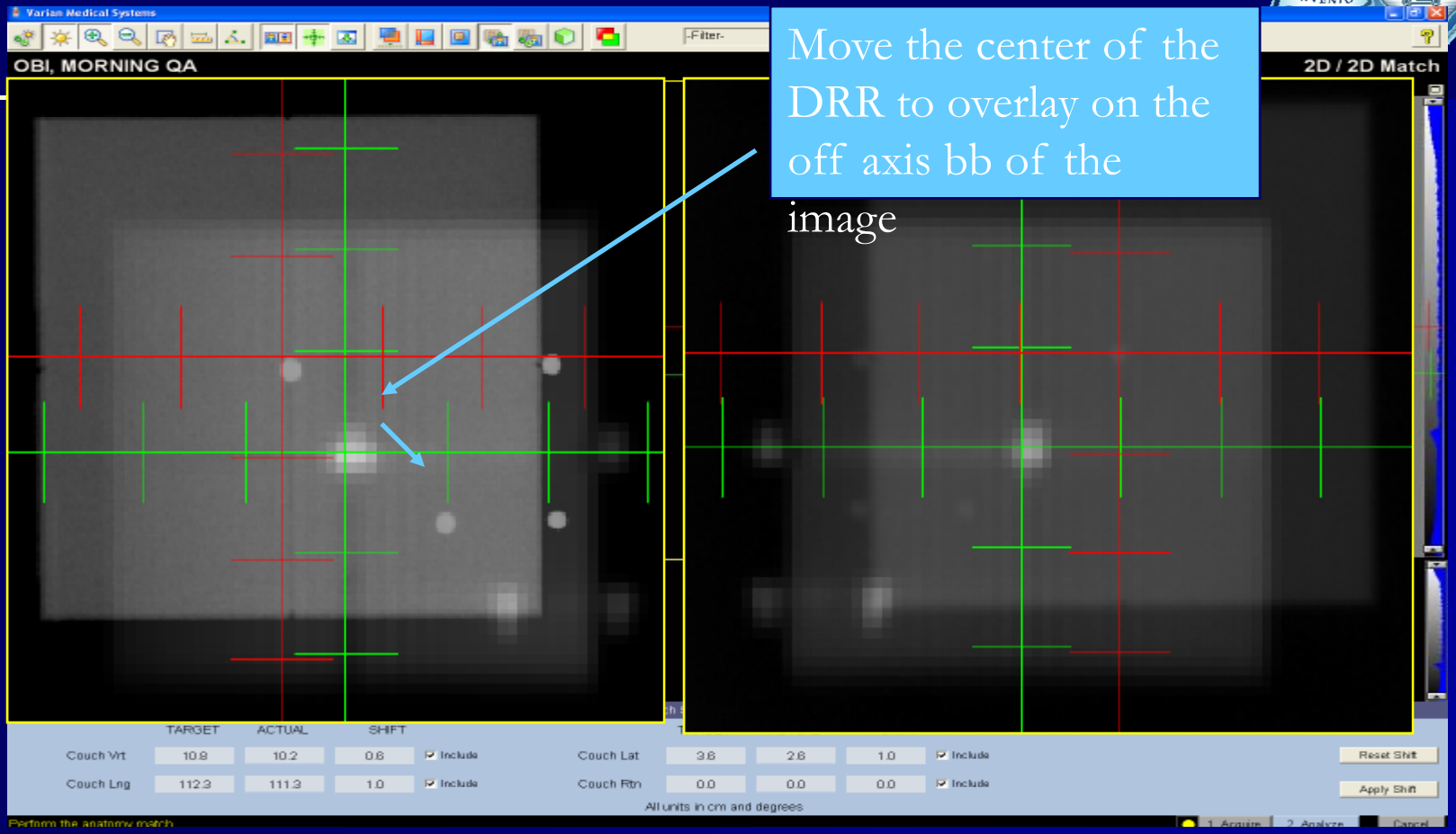
OBI: Daily QA- Test 1



OBI Isocenter Accuracy QA



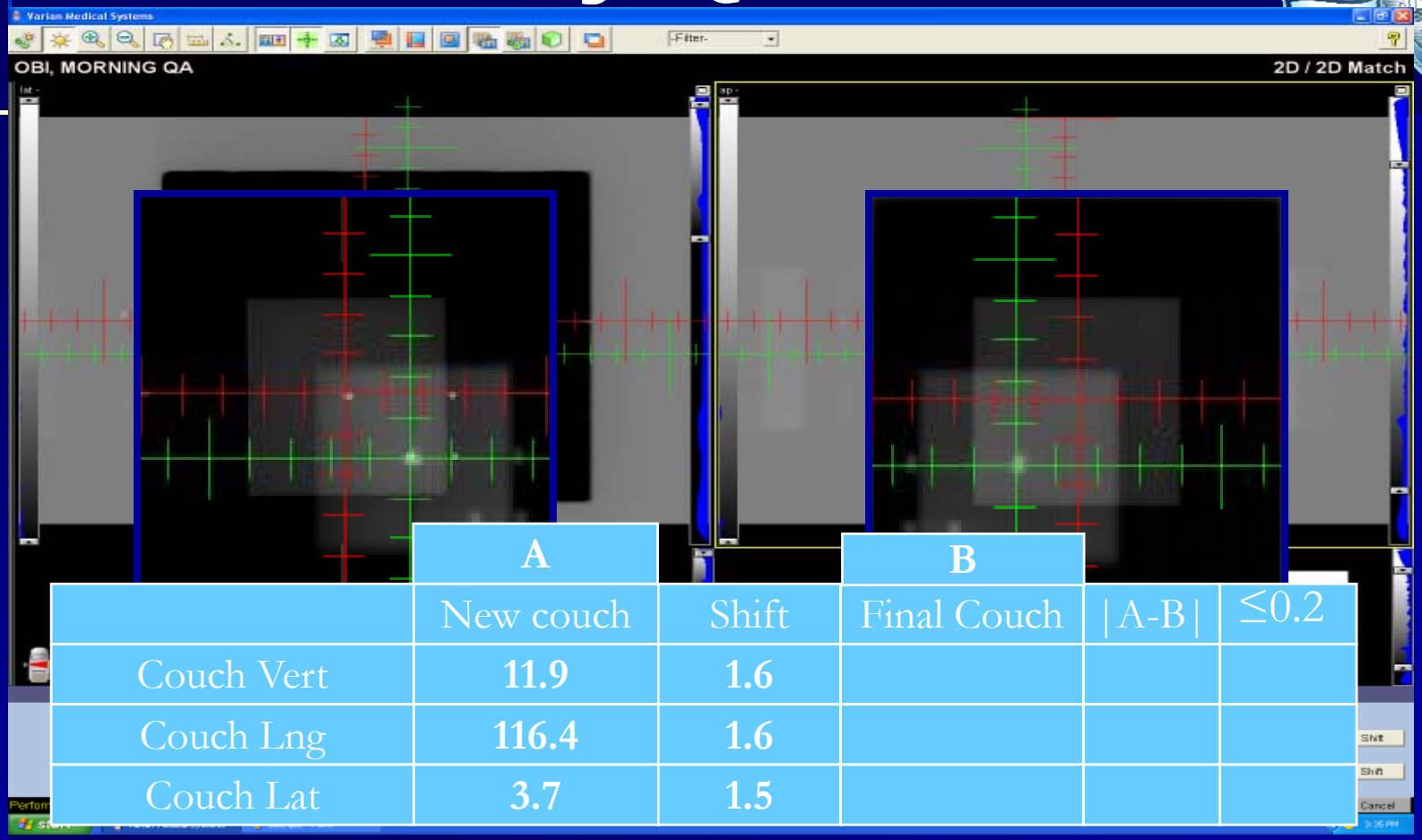
OBI: Daily QA-Test 2



Move the center of the DRR to overlay on the off axis bb of the image

If test 1 is acceptable, the DRRs (AP & Lat) were moved to overlay on the off-axis bbs of the images

OBI: Daily QA-Test 2

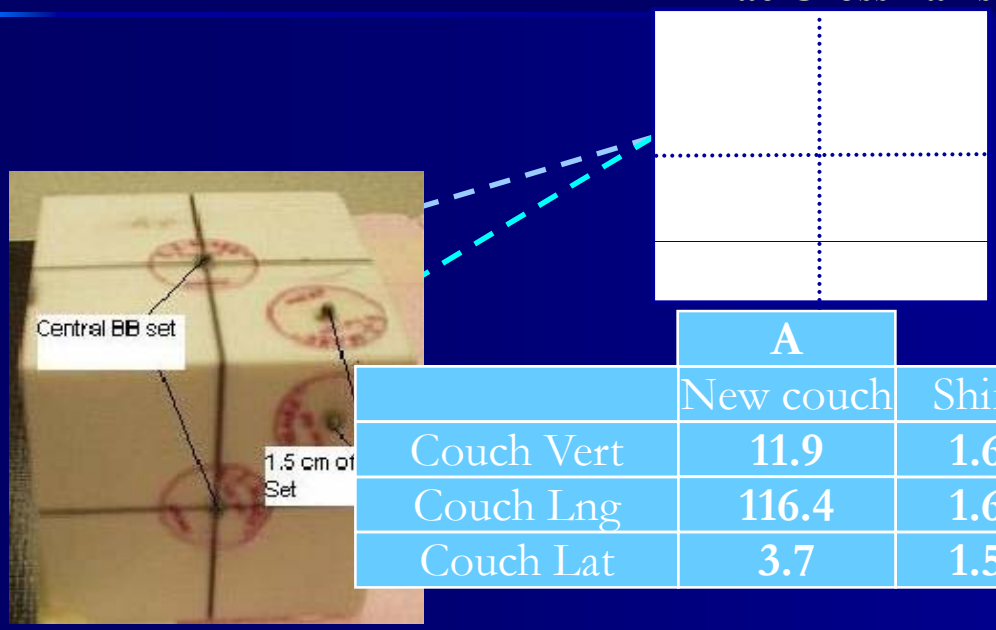


	A		B		
	New couch	Shift	Final Couch	|A-B|	≤0.2
Couch Vert	**11.9**	**1.6**			
Couch Lng	**116.4**	**1.6**			
Couch Lat	**3.7**	**1.5**			

The shifts obtained will be applied to remotely move the couch. The shifts and the new couch positions will be recorded

OBI: Daily QA-Test 2

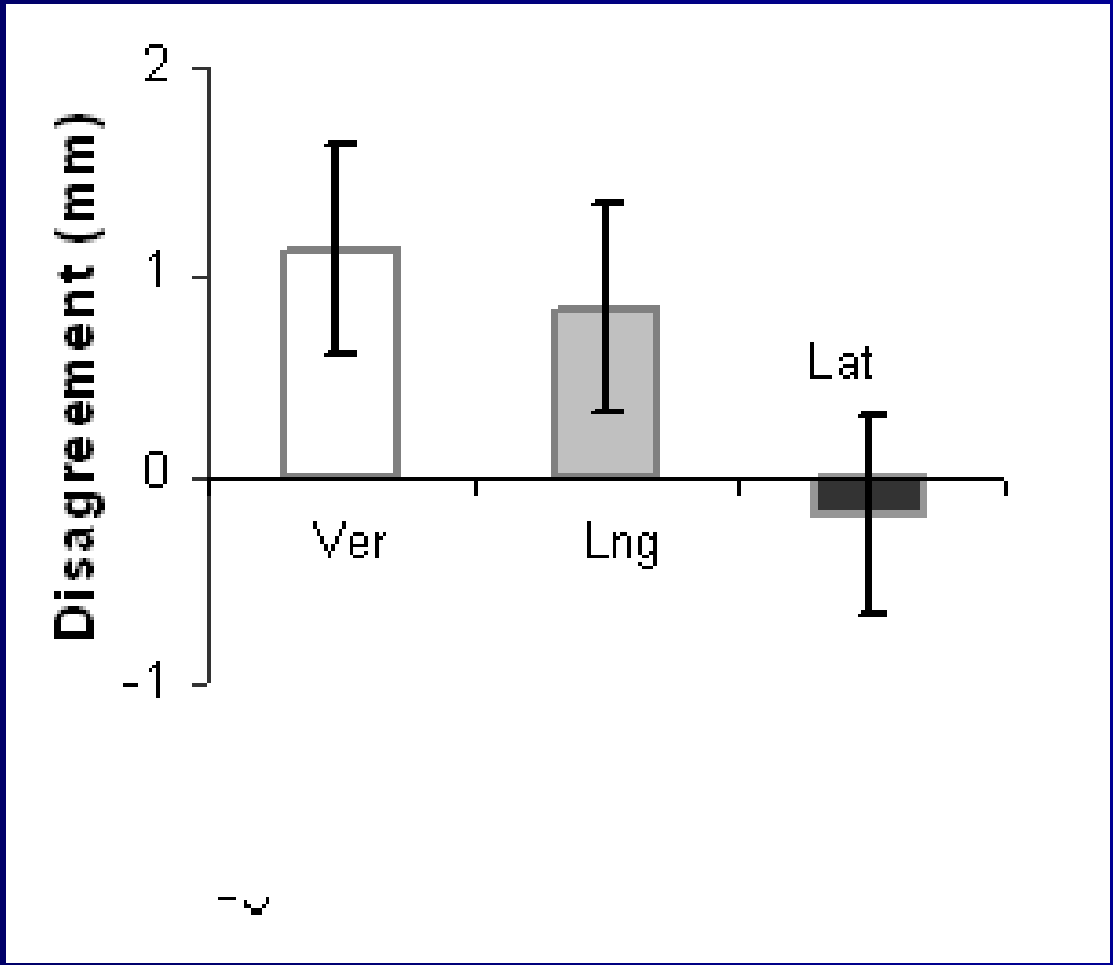
Linac Cross hairs



	A		B		
	New couch	Shift	Final Couch	| A-B |	≤0.2
Couch Vert	**11.9**	**1.6**	11.8	**0.1**	OK
Couch Lng	**116.4**	**1.6**	116.5	**0.1**	OK
Couch Lat	**3.7**	**1.5**	3.7	**0**	OK

- Cross hairs projected from the linac should cross the off- axis bb set on the phantom
- Manual couch motion might be needed to assure the overlay of the cross hairs and the center of the off-axis bb set
- Final couch positions will be recorded. The difference between the final and new couch positions should be within 2 mm

Results:2D/2D match



Summary-Daily QA

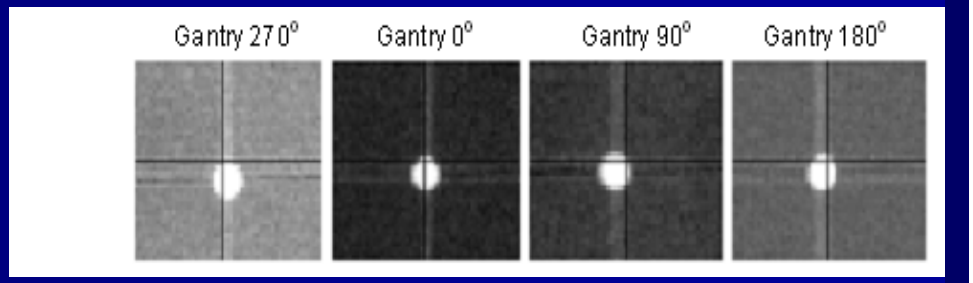
- The suggested QA tests assure reliable portal images for verification of daily patient positioning
- The procedure is simple and easy to implement. It takes about 10 minutes to do the QA
- Accuracy the procedure can detect is better than 2mm

Monthly QA

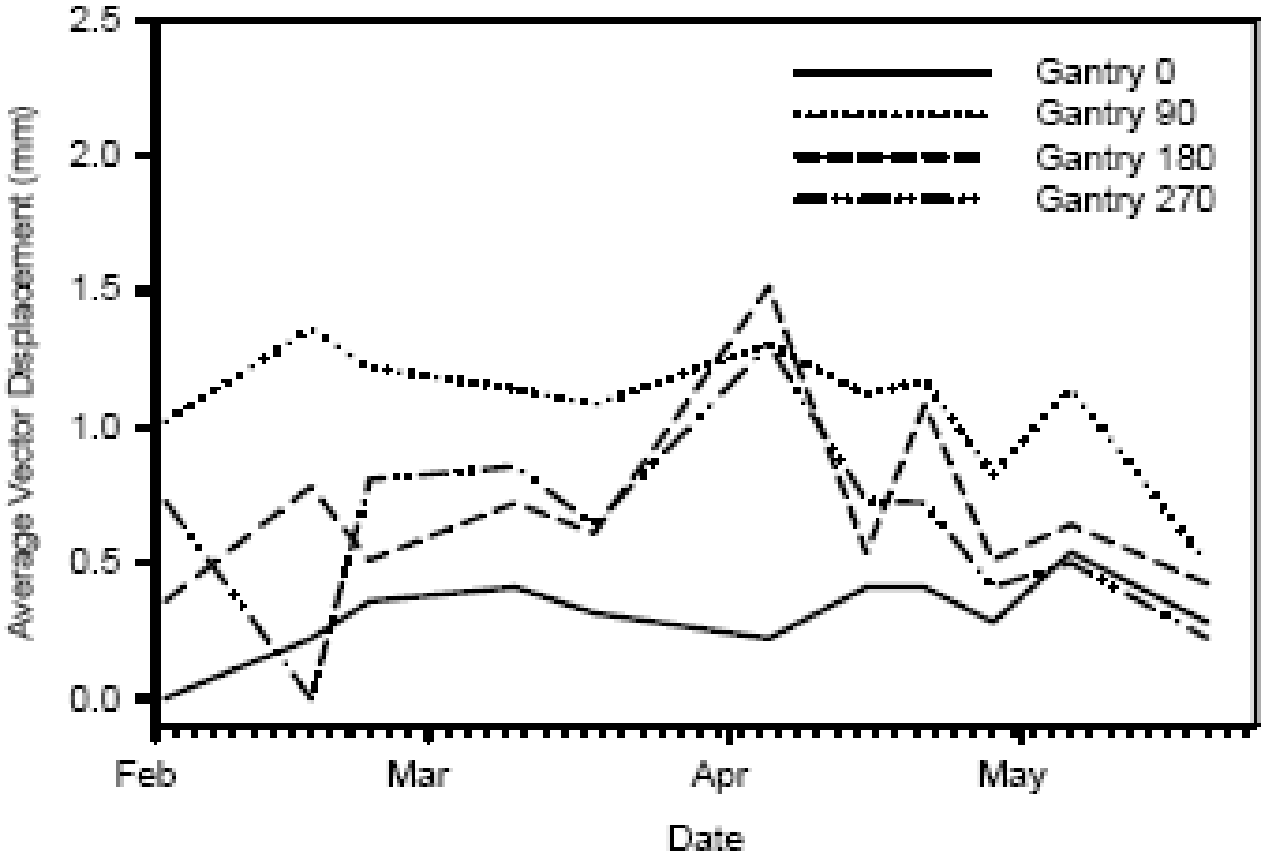
The monthly QA procedure includes isocenter accuracy over gantry rotation, checking collision interlock, mechanical center check, center reproducibility, digital measurement, and image quality of MVD, KVS and KVD

OBI isocenter accuracy over gantry rotation

- Acquiring KV images over multi gantry rotations
- Shown @ 4 gantry angles



Results-Gantry ISocentricty



Safety QA-Collision Interlocks

		MVD	KVS	KVD
Arm pedal	Alarm sound	☐	☐	☐
Device body	Alarm sound	☐	☐	☐
Motion disabled	Arm motion	☐	☐	☐
	Gantry motion	☐	☐	☐
	Couch motion	☐	☐	☐
	OBI console	☐	☐	☐

OBI Safety and functionality QA

- Tube warm up
- Door interlock
- Warning lights
- Storage space availability
- Database integrity

Mechanical QA (MVD)

1. Mechanical Center Check:
   - Measure distance between MVD cover @ (0,0,150) and isocenter
   - Measure offset between the mark and the c projected from Linac

	Distance	S/I (longitudinal) shift	R/L (lateral) shift
Reading (cm)			
Expected value (cm)	47.2 ± 0.2	≤ 0.2	≤ 0.2

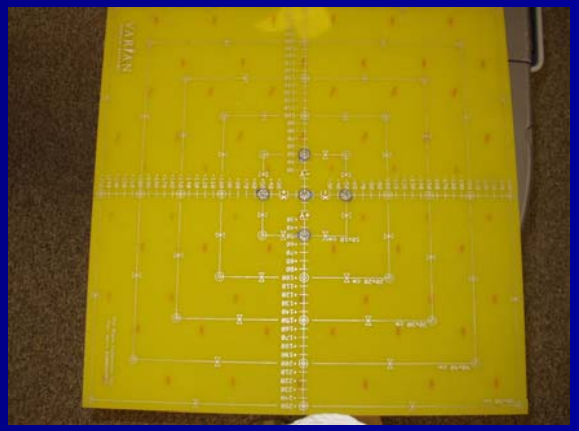
   - Run-out during arm vertical travel with MVD @ (0,0,130) Measure offset between the mark and the crosshair projected from Linac

	S/I (longitudinal) shift	R/L (lateral) shift
Reading (cm)		
Expected value (cm)	≤ 0.2	≤ 0.2

Mechanical QA (MVD)

- Digital Measurement Accuracy:

Place blade calibration tool @ isocenter, acquire MV image Using measuring tool from OBI to measure S/I R/L length of 10cm x 10cm square



	S/I (vertical) line	R/L (horizontal) line
Reading (cm) Expected value (cm)	10.0 ± 0.2	10.0 ± 0.2

Mechanical QA (KVD)

Mechanical Center Check:

Rotate gantry @ 90° so that KVD @ (0,0,150) is on the Floor

- Measure distance between grid surface and Isocenter
- Measure offset between the mark and laser projected

	S/I (longitudinal) shift	R/L (lateral) shift
Reading (cm) Expected value (cm)	≤ 0.2	≤ 0.2

- Run-out during arm vertical travel with KVD @ (0,0,130)

Measure offset between the mark and laser projected from ceiling

	Distance	S/I (longitudinal) shift	R/L (lateral) shift
Reading (cm) Expected value (cm)	48.2 ± 0.2	≤ 0.2	≤ 0.2

Mechanical QA (KVD)

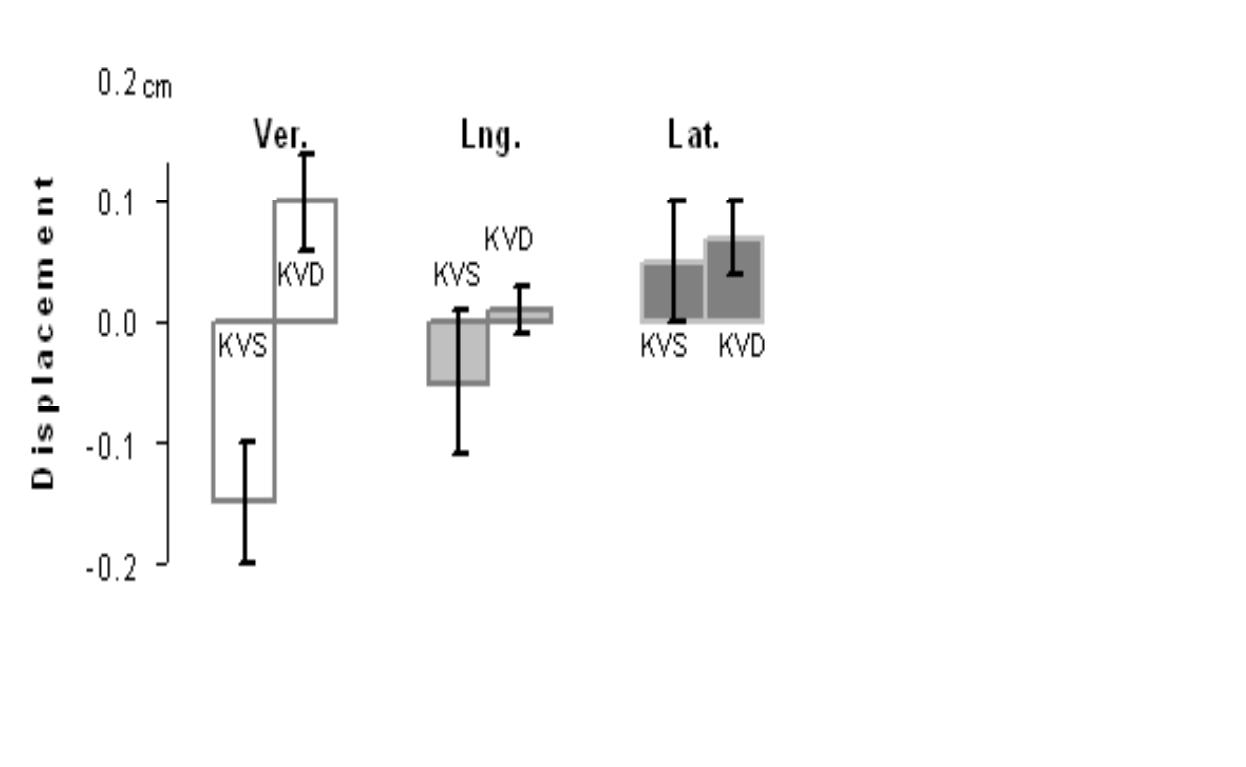
1. Mechanical Center Check:

Rotate gantry @ 270° so that KVS @ (0,0,100) is on the floor

- Measure distance between KVS plate and isocenter
- Measure offset between the mark and laser projected from ceiling

	Distance	S/I (longitudinal) shift	R/L (lateral) shift
Reading (cm) Expected value (cm)	85.2 ± 0.2	≤ 0.2	≤ 0.2

Results



KVD & KVS mechanical displacement over 1 year period

Image Quality QA

- To establish baseline for image quality parameters and to monitor these parameters over time
- Adopted tests from conventional QA programs for radiographic units

Image Quality (MVD)

Set MVD @ (0,0,150) and place the *Vegas Phantom* on the top of MVD .

- Acquire MV high quality image
- The max R visible in C1 determines contrast, and the max C visible in R1 determines resolution

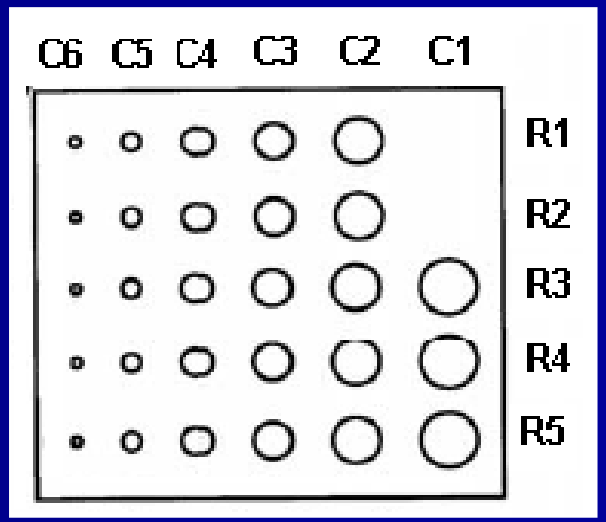


Image Quality (KVS/KVD)

Set KVD @ (0,0,150) and place the *Leeds Phantom TOR 18FG* on the top of KVD

18 disks of 8 mm diameter each with contrast ranging between 16.7% and 0.9% and central 21 bar patterns ranging between 0.5 to 5 lp/mm

- **Contrast:** Acquire single high quality image and fluoroscopic mode ~(70 kVp, 25 mA, 6 ms) with 1 mm copper plate over KVS

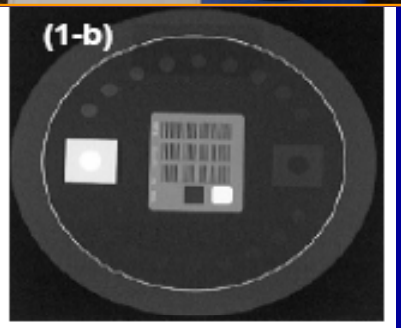
  The number of visible disks along the rim determines the contrast

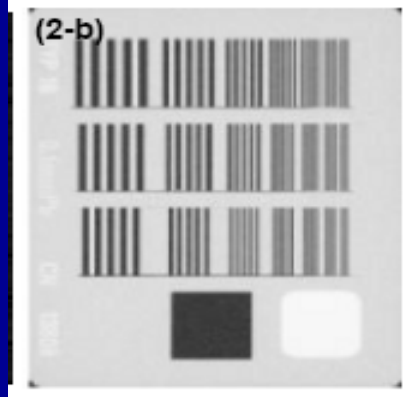
  11 (3.2%) or 12 (2.7%) contrast disks or more should be discernable

- **Spatial Resolution:** Take a KV radiographic and fluoroscopic exposure ~(50 kVp, 80 mA, 32 ms)

  Select the smallest visible group of line pairs

  11th group of bars, equivalent to 1.6 lp/mm should be visible



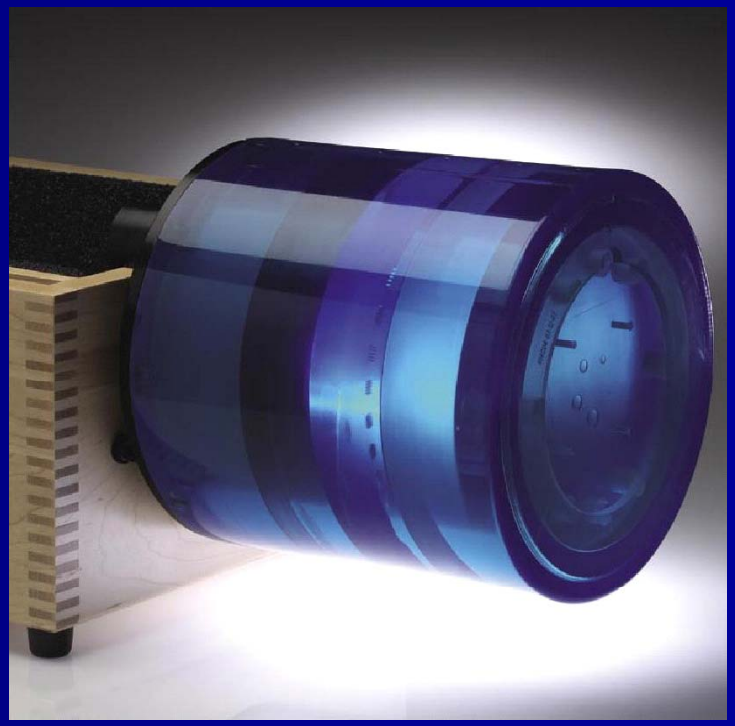


CBCT QA

- Didn’t include a separate geometric measurement for CBCT images
- Geometry of KV radiographs and CBCT images depend upon the position of the OBI arms

CBCT Image quality

- QA tests adopted from diagnostic CT scanners
- Alternate check of full-fan and half-fan modes
- Use the Catphan 504 phantom
- Scan acquired 125 kVp, 80 mA, 25 ms 150 SID with 512x512 reconstruction matrix and 2.5 mm slice thickness



HU Accuracy

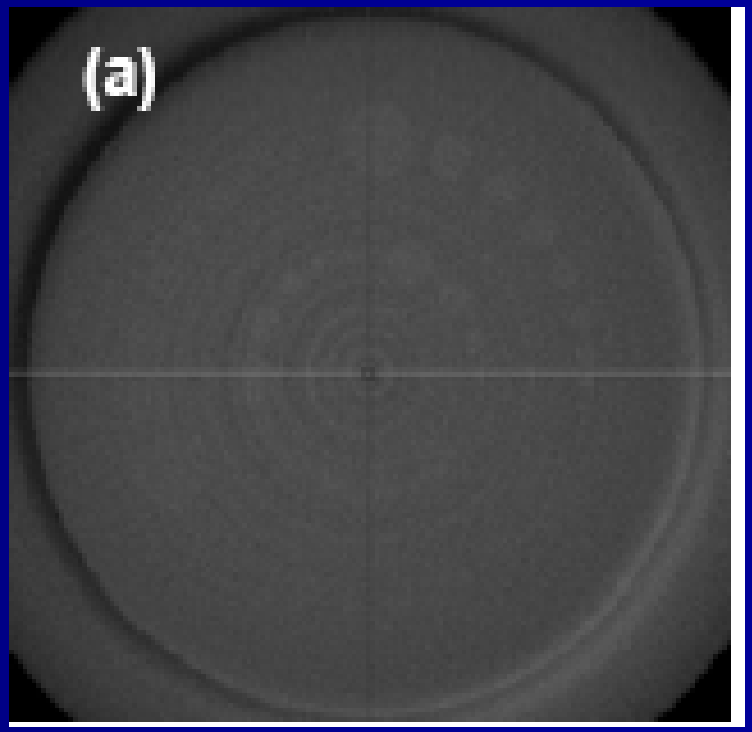
- CTP 404 inserts contains 7 materials of different densities
- Using ROI 0.7x0.7 cm
- HU values should be within 40 HU

HU Accuracy-*OBI 1.3*

		Full-Fan		Half-Fan	
	Expected HU	Measured HU	Diff.	Measured HU	Diff.
Air	- 1000	- 1024	- 24	- 1024	- 24
PMP	- 200	- 193	+ 7	- 188	+ 12
LDPE	- 100	- 92	+ 8	- 97	+ 3
Polystyrene	- 35	- 45	- 10	- 30	+ 5
Acrylic	120	125	+ 5	137	+ 17
Delrin	340	354	+ 14	361	+ 21
Teflon	990	961	- 29	982	- 8
		Tolerance	$< \pm 40$	Tolerance	$< \pm 40$

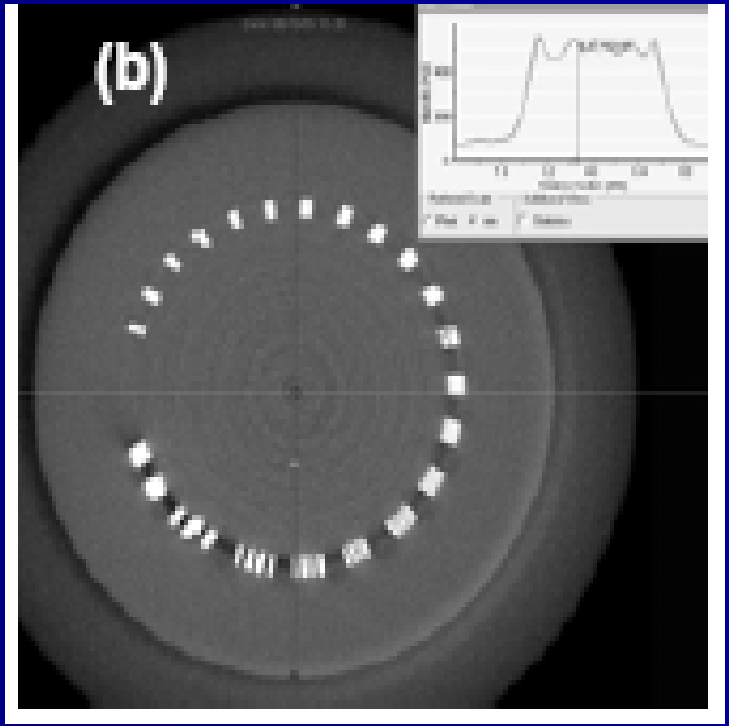
Low Contrast Resolution

- CTP 515 insert 3 groups of supra-slice disks with diameters ranging from 2-15 mm and subject contrasts of 1%, 0.5%, and 0.3%
- Recommendation 1%, 7 mm disk



Spatial Resolution

- CTP 528 insert contains a spatial resolution rule with bar patterns between 1 to 21 lp/cm
- Recommendation 6lp/cm



HU Uniformity

- CTP 486 insert is a uniform disk of 20 cm diameter
- Area profile used 5 ROIs
- Within 40 HUs

Summary

- The complex nature of the radiation therapy process and the need to produce a patient specific treatment that maximizes the therapeutic ratio requires “proper” integration of IGRT systems into the process

- This requires significant effort to implement and to employ

Summary

- OBI is one of these systems designed to correct for motion and setup errors of patients
- We presented a QA program to monitor the mechanical and image quality of the system
- The tests use tools and phantoms provided with the OBI system
- Since OBI is a device to improve geometric accuracy of patient treatments, the most critical tests are those of its mechanical stability/accuracy

Summary

- Measurements show that mechanical stability of the OBI system is quite high with SD of 0.3 to 0.4 mm over 1 year period monitored by the geometric positioning of the arms
- Tests were useful in detecting performance deficits
- Implementation of QA tests, methods, frequency, and tolerances could vary. However, it s important to establish a guideline

Summary

- More work should be done on improving image quality
- Smooth flow of data
- More work on automatic fusion

Thank You