



CONNECTING LIFE AND SCIENCE

MR Guided Radiation Therapy: ViewRay System

Sasa Mutic, Ph.D.



Conflict of Interest Statement

- Shareholder - ViewRay Inc.
- Clinical advisory board - ViewRay Inc.
- Research and service - ViewRay Inc.

Learning objectives

- Describe the ViewRay system
- Describe the system evaluation and preparation for clinical implementation
- Present some research and clinical projects

ViewRay System at Washington University

- A commercial system (FDA approved) acquired for clinical service and research
- Two functioning systems
 - St. Louis – Washington University
 - Cleveland – ViewRay
- Two systems in installation
 - University of Wisconsin – Madison
 - University of California – Los Angeles

ViewRay at Washington University



- 0.35T MR
- 3 Co-60 heads – (~ 550 cGy/min @ iso)
- 3 fully divergent MLCs (minimized penumbra)
- Large imaging FOV (50 cm) and Tx volume (27cmx27cm)
- Conformal RT and/or IMRT
- Integrated planning system
 - Monte Carlo dose calculation
 - Fast optimization and calculation (9 field plan ~ 30 sec)
- Continuous MR Therapy Control

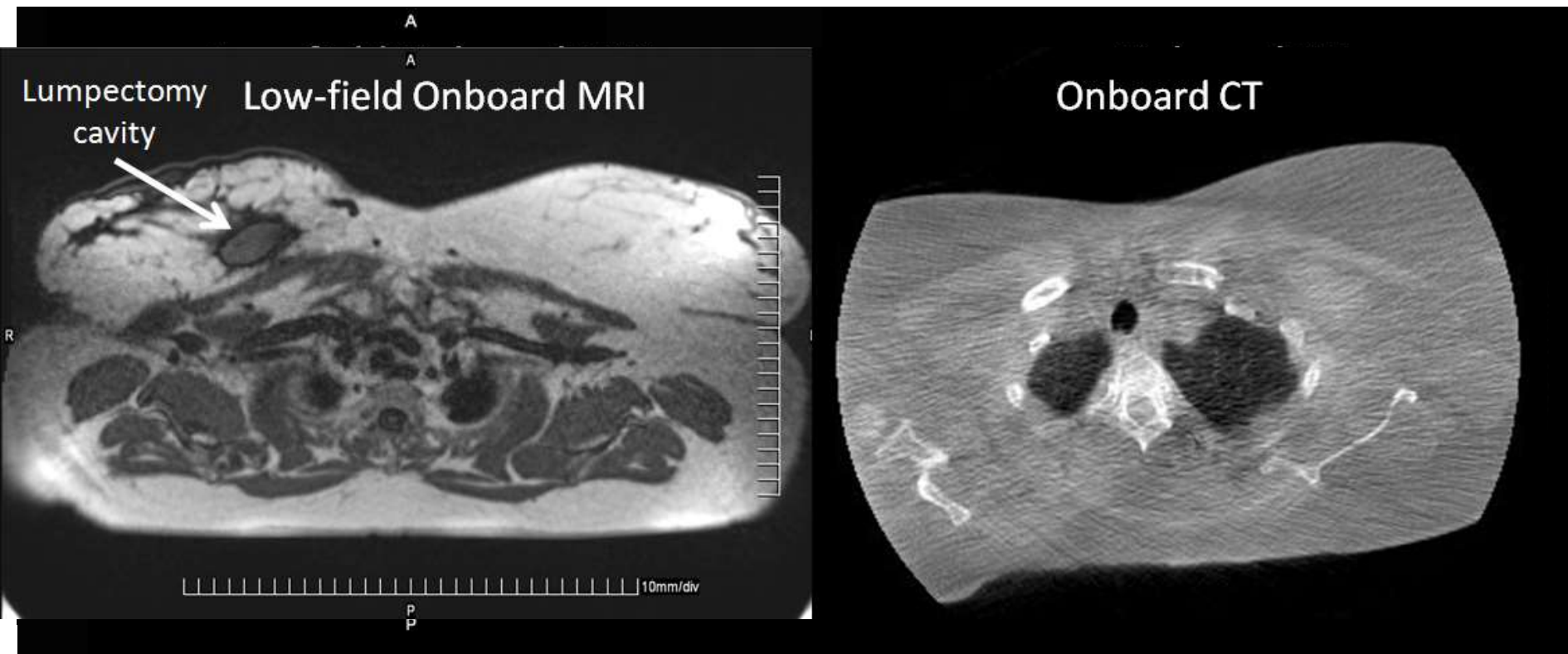


Imaging System Evaluation

- ViewRay Imaging
 - Split Supercon 28 cm gap, 0.345 T, 14.7 MHz 50 cm DSV, warm bore 1.05 m
 - Split Gradient 28 cm gap, 5 mm former in gap, slew 200 mT/m/ms, 18 mT/m peak, 30 kW heat removal
 - Isocenter matched to RT Iso (2mm)
 - Body coil & surface coils -thin uniformly attenuating, electronics out of the beam
- Evaluation
 - FDA testing and acceptance testing (manuscript in preparation)
 - Clinical comparison of onboard MR and CT (manuscript submitted)

Imaging System Evaluation

Clinical study comparing 0.35T MR and CBCT

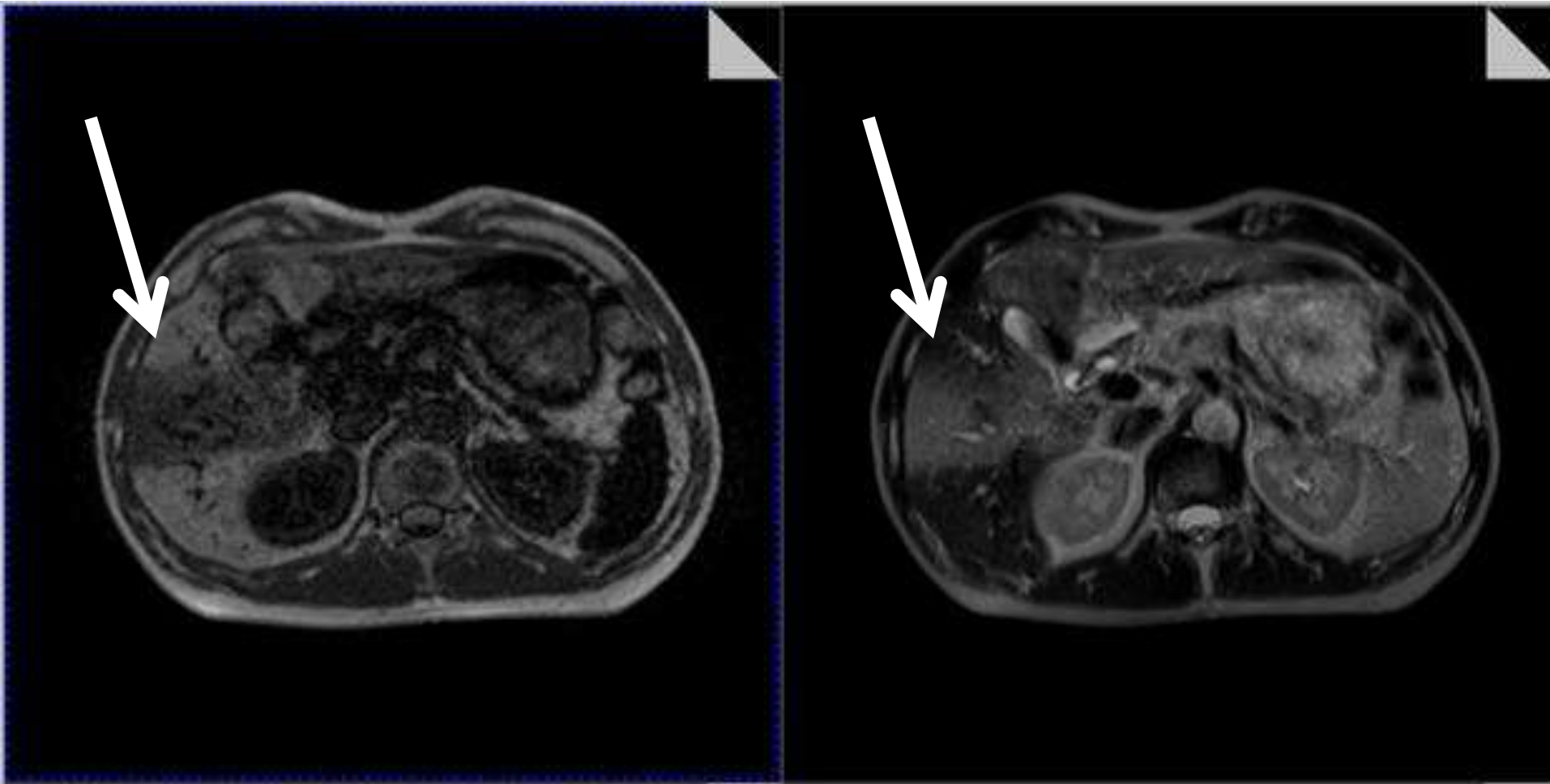


Washington University Study

Noelle, C. et. al., manuscript submitted

What else can we see with MR?

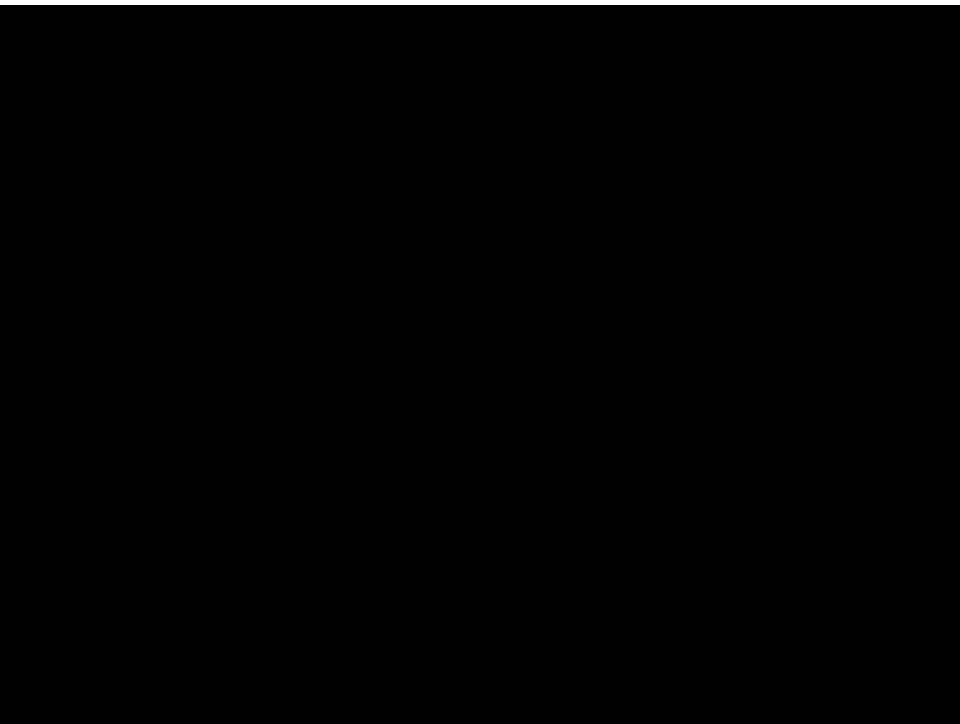
Radiation Damage - Edema



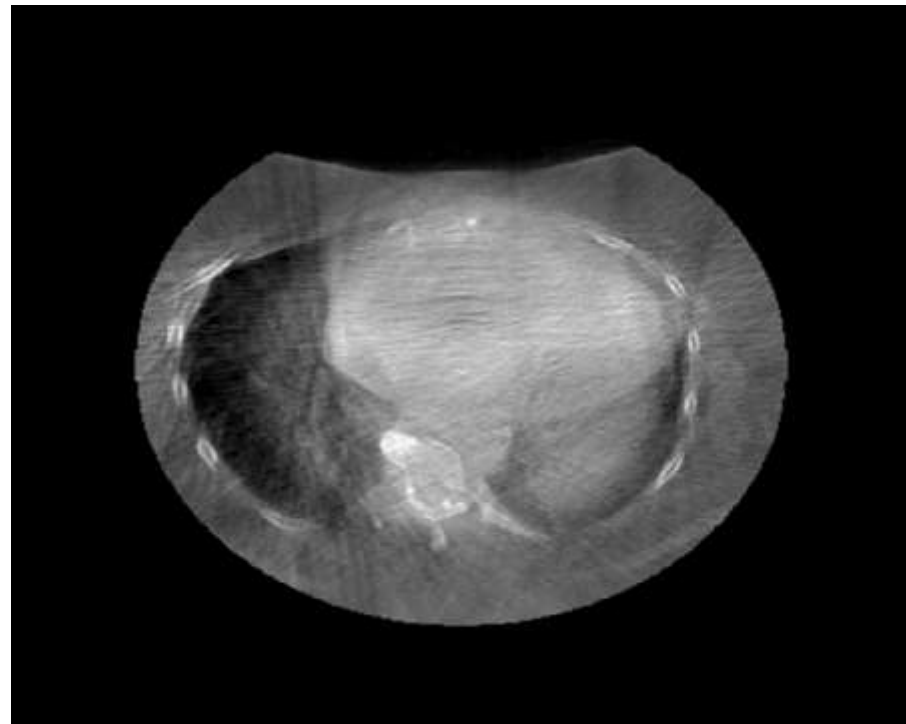
Washington University Study

Imaging system evaluation

Clinical study comparing 0.35T MR and CBCT



Onboard MR



Onboard CT

Treatment Planning System Evaluation

- Dedicated TPS
 - Integrated from prescription through delivery and adaptive therapy (including on couch optimization and planning)
- Supports only Monte Carlo based calculation with and without magnetic field effects
- Beam numbers in increments of 3 (3 heads)
- Planning on CT or MR
- FDA related testing, acceptance testing, clinical plan comparison studies

Treatment Planning System Evaluation

The screenshot displays a Treatment Planning System (TPS) interface. The main window shows a transverse CT scan of the pelvis with several contours: a yellow contour for the prostate, a red contour for the rectum, and two blue contours for the femurs. The interface includes a top toolbar with various icons, a central DVH (Dose-Volume Histogram) window with tabs for DVH, Plan-Rx Comparison, and Statistics, and a right-hand panel for patient information and display settings.

Patient Information:

- Patient: Pelvis, ASTRO
- prostate001
- MRN: [blank]
- DOB: 02/03/1970
- Diagnosis: TMRT Testing
- Site: Other
- Quick Prescription: Rx
- T: [blank] N: [blank] D: [blank] M: [blank] Y: [blank]
- OTK v3 Plan Test
- Position: HPS

Dose and Display Settings:

- Dose:** Includes fields for Dose, Units, and a table for organ-at-risk (OAR) constraints.
- Display:** Includes checkboxes for Image View, Structures, Points of Interest, Beams, Dose View, and Couch Display.

Estimated Treatment Beam-On Time: 0.00 minutes per fraction

Organ-at-Risk (OAR) Constraints Table:

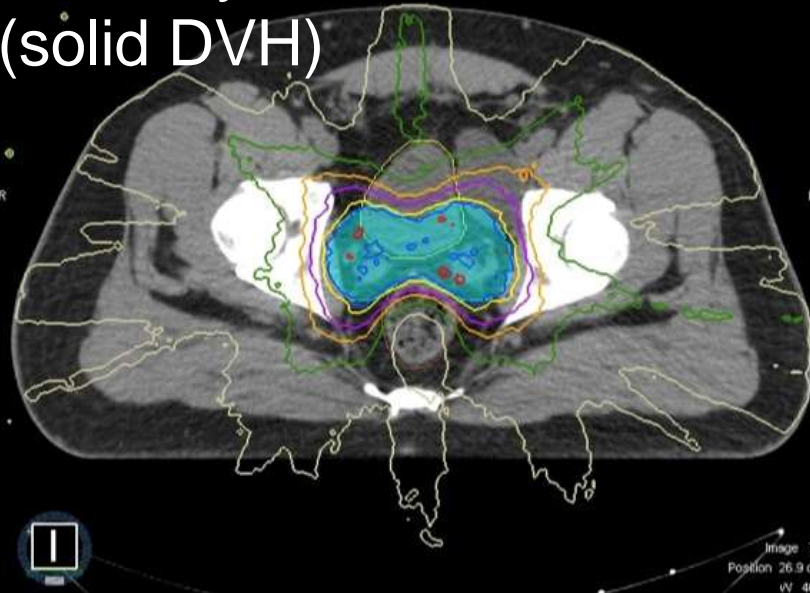
Structure	Constraint	Value	Unit	Priority	Weight	Score	Grade	Comment
Skin	TD50/5	50	Gy	High	1.0	0.0	1	
Bladder	TD50/5	50	Gy	High	1.0	0.0	1	
Prostate	TD50/5	50	Gy	High	1.0	0.0	1	
Rectum	TD50/5	50	Gy	High	1.0	0.0	1	
Femur, Right	TD50/5	50	Gy	High	1.0	0.0	1	
Femur, Left	TD50/5	50	Gy	High	1.0	0.0	1	
Bowel	TD50/5	50	Gy	High	1.0	0.0	1	

Footer:

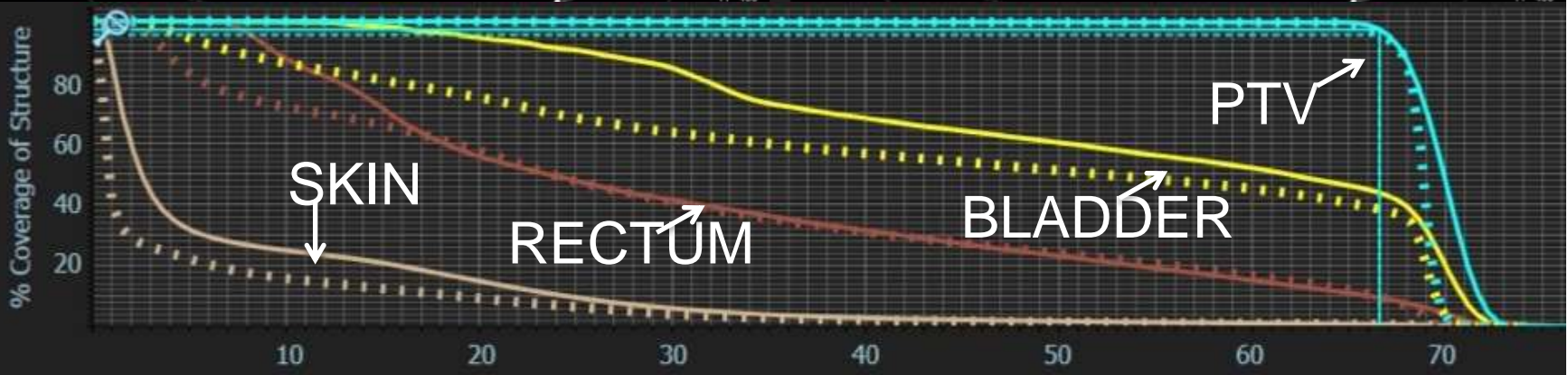
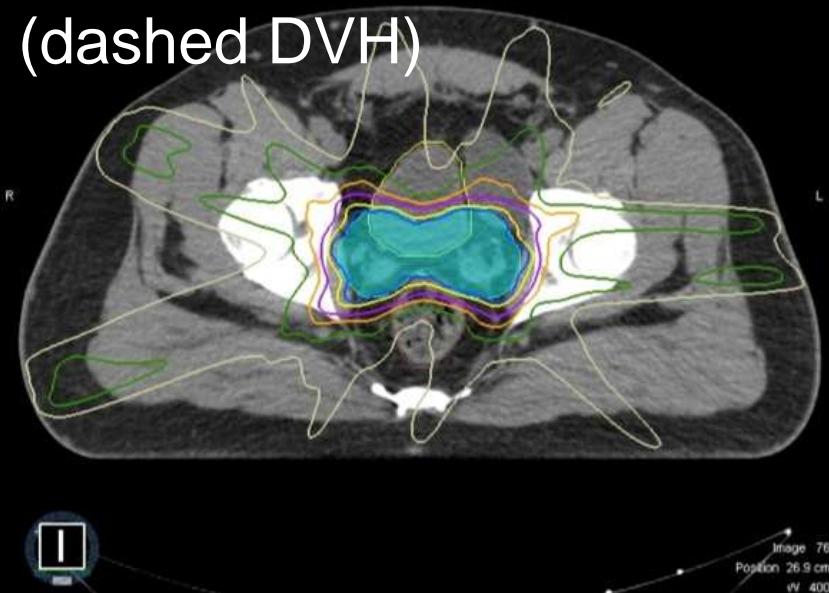
- Calculating Dose [Cancel]
- For Research Use Only. Not for Human or Clinical Use.
- IEC 61217 Compliant.
- Mar 23 2013 2:43PM

Treatment Planning System Evaluation

ViewRay
(solid DVH)



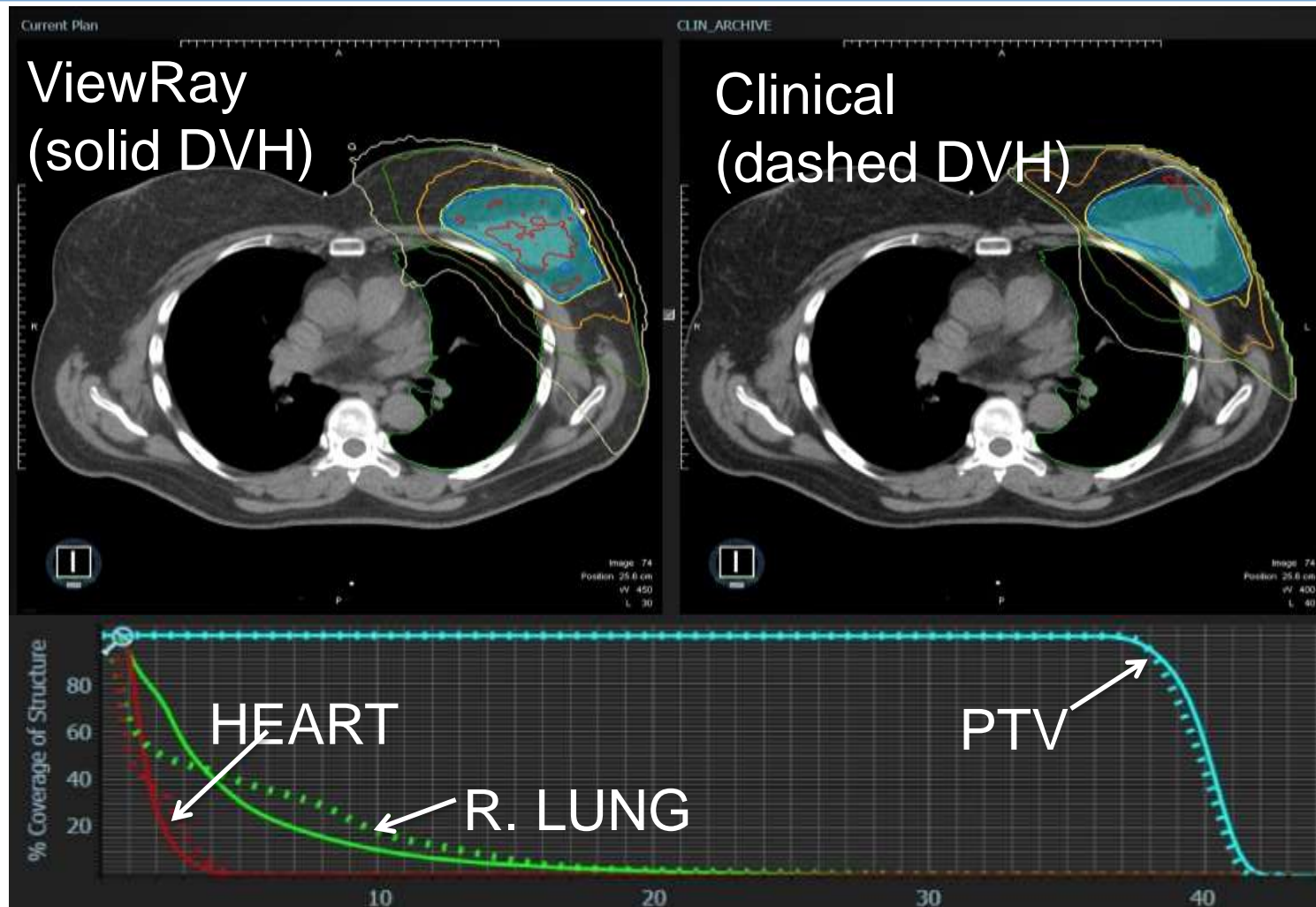
Clinical
(dashed DVH)



ViewRay: ^{60}Co IMRT

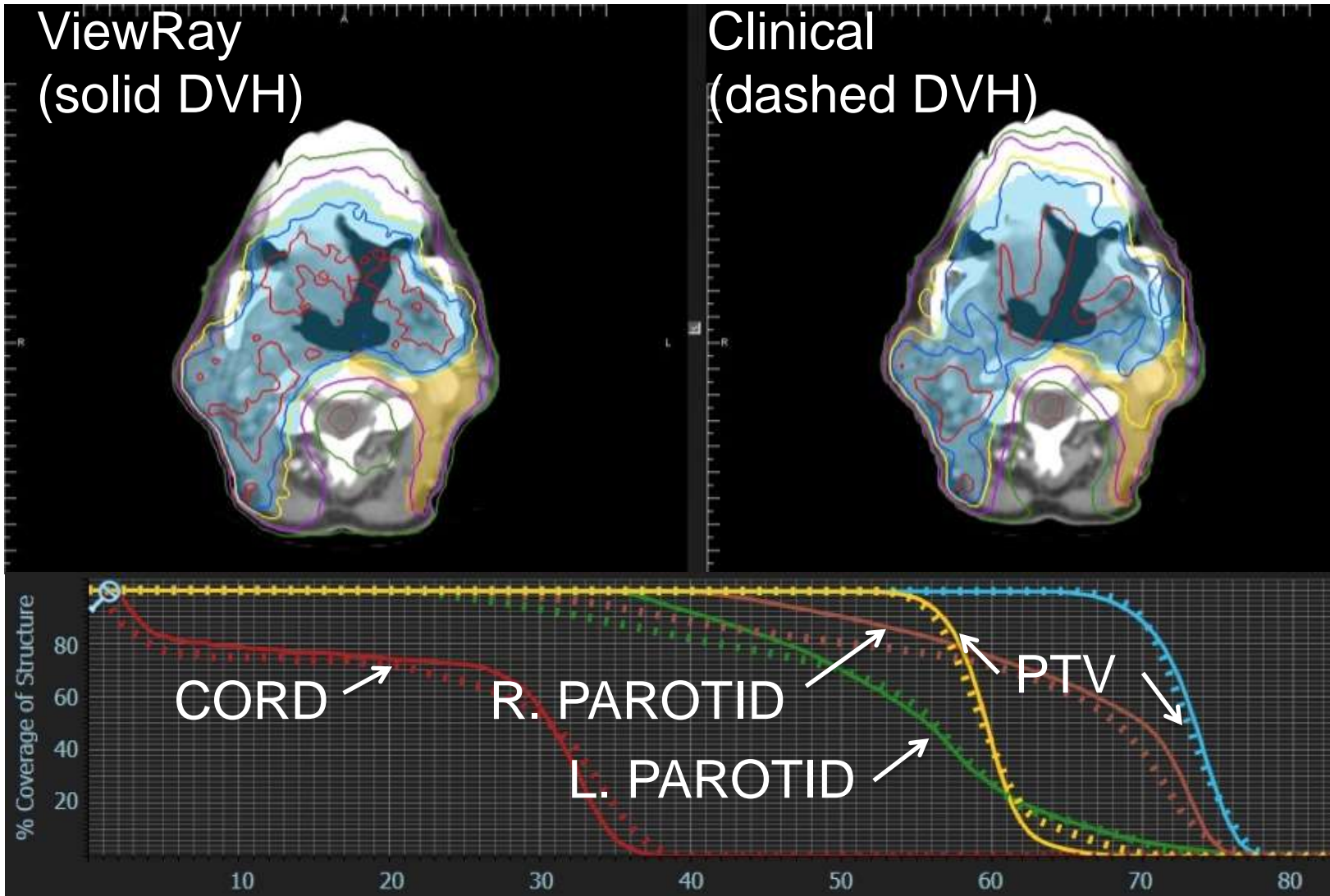
Clinical plan: 18 MV IMRT

Treatment Planning System Evaluation



Clinical plan: 3D conformal using non-coplanar 6 MV beams.
ViewRay: ^{60}Co coplanar IMRT

Treatment Planning System Evaluation



ViewRay: ^{60}Co IMRT

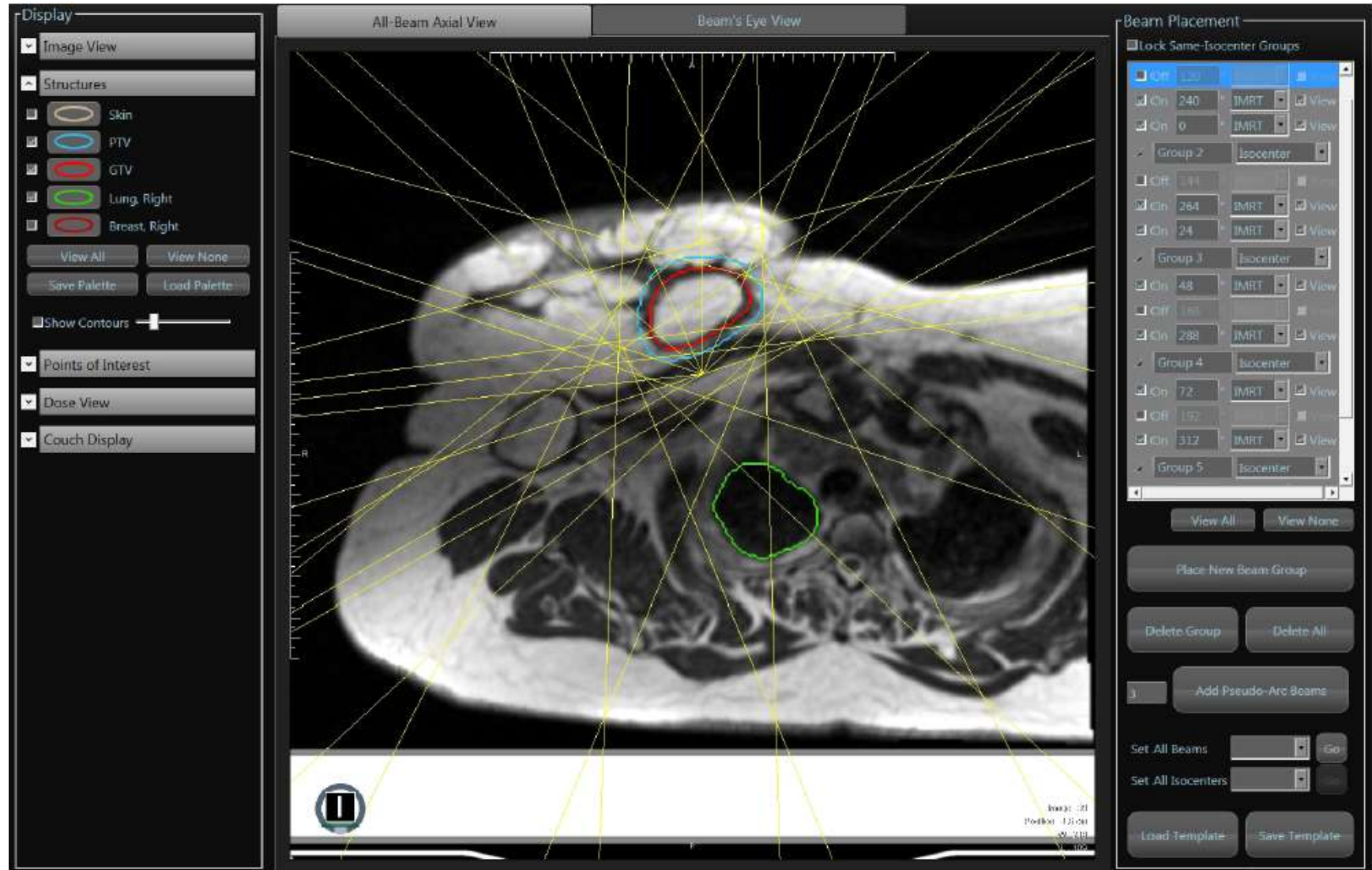
Clinical plan: Definitive 6 MV IMRT

Delivery Evaluation

- **Conventional:**
 - IGRT machine with three heads and all related geometric and dosimetric concerns (TG142, TG51, etc.)
- **Novel:**
 - On couch dose prediction, re-optimization and calculation
 - MR Controlled Treatment (realtime accounting for target position and shape)
 - Two headed mode (if there is a problem with one head)
- Phantom and simulated delivery with patient data studies
- QA tools and methods, immobilization, workflow, practicality, etc.

Workflow – Initial Planning on CT or MR

Beam Setup



Workflow – Initial Planning on CT or MR

Planning



Workflow – Daily Imaging and Contouring

High res with contour propagation and deformation (as desired)

Image Volumes

Imaging Setup

- ☒ Pilot Volume
- ☒ High-Resolution
- FOV: LR40 x AP50 x HF2
- Res: 1.5 mm x 1.5 mm
- ☒ Use Navigator
- Lateral: [0]
- Axial: [0]
- Vertical: [0]

Sequence Settings

- Imaging Time: 210
- SAR Operating Mode: Normal (0.095595926)
- dB/dt Operating Mode: First Level (105%)
- Acquire High-Resolution Volume

Plan Image

Current Image

Process and Plan

- Get Deformation and Auto-Contour
- Auto-Contour Skin: Threshold 134, Margin 5
- Rigid Copy Contours
- Edit Contours

Get Couch Shift

Manual Automatic

☒ Rigid ☒ Deformable

Set Isocenter Manually Find Shift From Fusion

Mark 3-Point Setup Set to center of [] Find

Couch Location

	Plan Position	Actual Position	Displayed Shift
Lateral	0.3 cm	0.3 cm	0 cm
Vertical	-18.4 cm	-18.4 cm	0 cm
Axial	226.7 cm	226.7 cm	0 cm

Send Shift to Couch

Display

- ☒ Image View
- ☒ Positioning Scan View
- ☒ Electron Density View
- ☒ Structures
- ☒ Points of Interest
- ☒ Couch Display

Workflow – Daily Dose Control

Dose prediction or full re-optimization and dose calculation on table

Planning Image

Current Image

Display

- ☒ Image View
- ☒ Positioning Scan View
- ☒ Structures
- ☒ Points of Interest
- ☒ Dose View

Colorwash

Dose Opacity: 0.5

Isodose Lines

- ☒ 42.35 Gy 110.0%
- ☒ 38.50 Gy 100.0%
- ☒ 34.65 Gy 90.0%
- ☒ 30.80 Gy 80.0%
- ☒ 26.95 Gy 70.0%
- ☒ 23.10 Gy 60.0%
- ☒ 19.25 Gy 50.0%
- ☒ 15.40 Gy 40.0%
- ☒ 11.55 Gy 30.0%
- ☒ 7.70 Gy 20.0%

DVH | Plan-Rx Comparison | Statistics

Structure/Point	Min	Mean	Max	Dose to Volume		
Breast, Right Rx				< 35	% at	38.5 Gy
Original Plan	0.23	10.71	41.91	26.86	% at	16 Gy
Predicted	0.22	10.71	41.77	26.87	% at	16 Gy
Breast, Right Rx				< 35	% at	38.5 Gy
Original Plan	0.23	10.71	41.91	4.92	% at	38.5 Gy
Predicted	0.22	10.71	41.77	4.86	% at	38.5 Gy
PTV Rx				>= 95	% at	38.5 Gy
Original Plan	36.49	39.70	41.91	95.00	% at	38.5 Gy
Predicted	36.20	39.66	41.77	94.36	% at	38.5 Gy

Dose

- Predict Original Plan Dose on Current Images
- Re-Optimize Dose to New Plan
- Normalize New Plan
- Exit New Plan to Planning Workspace

Finalize Treatment Plan

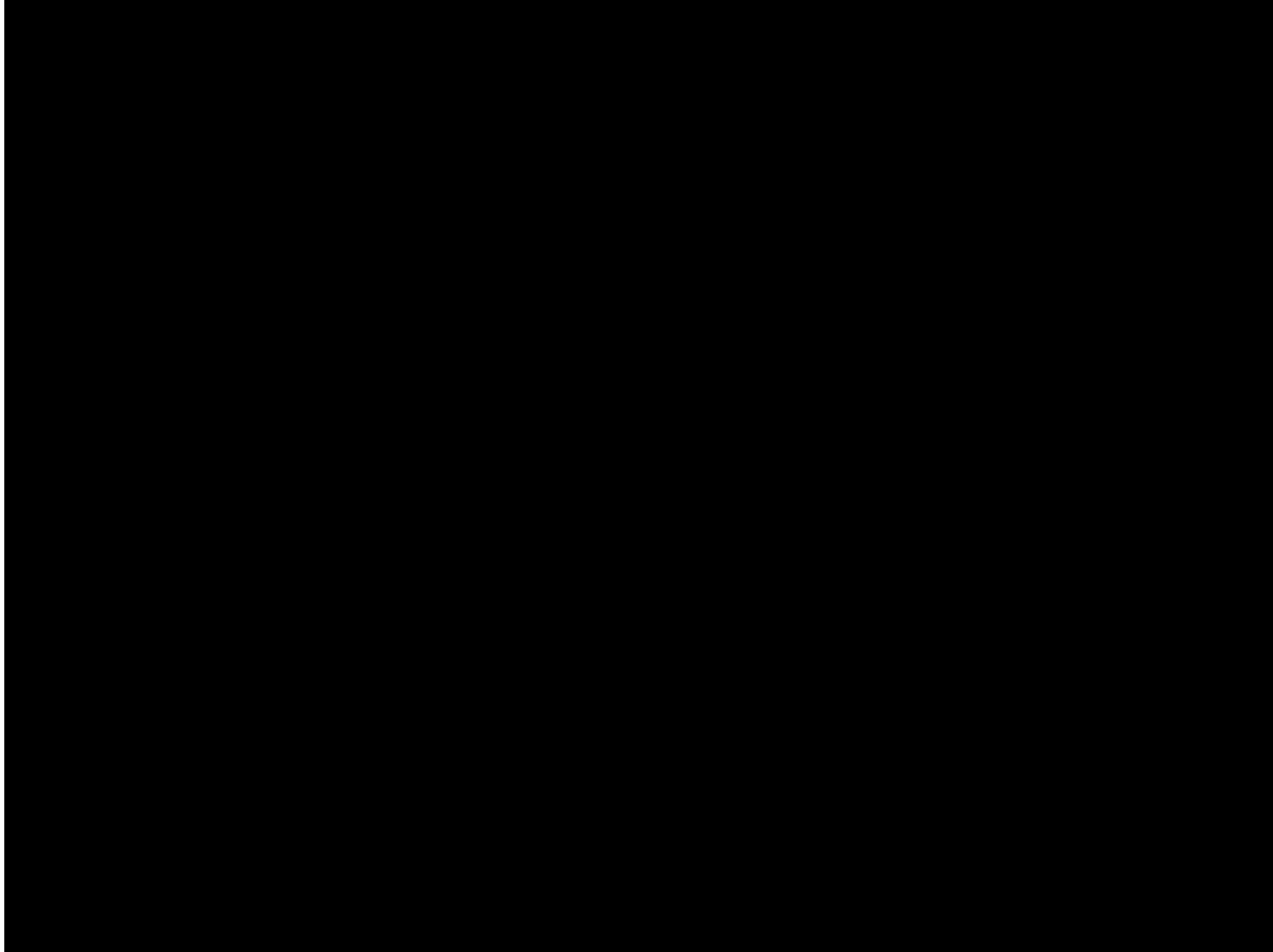
Compare Approved Planning Dose to:

Predicted Original Plan Dose

- ☒ Treat with Original Plan
- ☐ Treat with New Plan

Workflow – MR Controlled Treatment

Fast imaging and real time target delineation



Workflow – MR Controlled Treatment

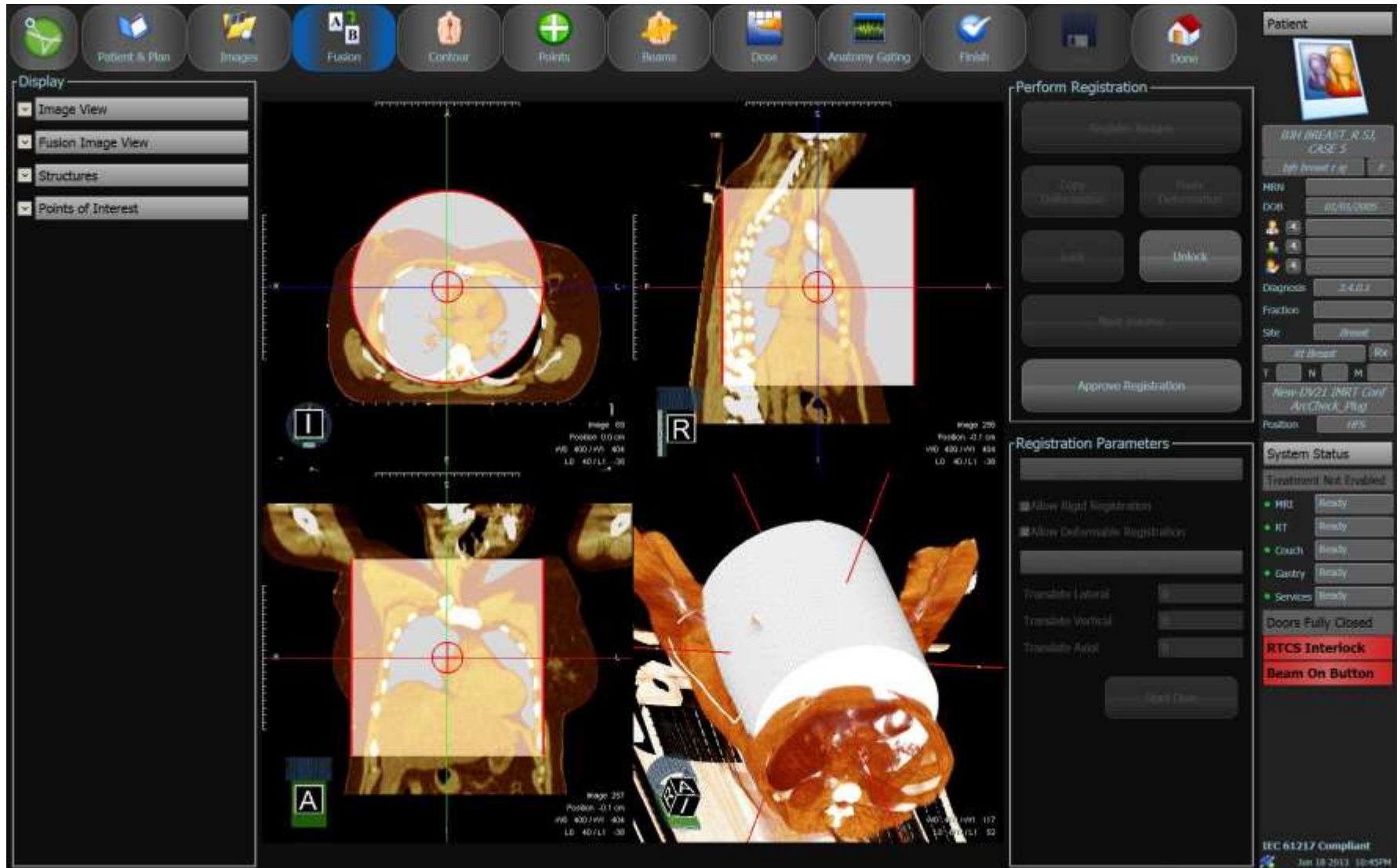
Fast imaging and real time target delineation

The interface is divided into several sections:

- Treatment Controls:** Includes buttons for "Double Treatment", "Pause", "Resume", and "End Treatment Early".
- Treatment Status:**
 - Buttons for "SLAM Off" and "Target In Bounds".
 - A circular diagram showing the gantry's position.
 - A list of segments and their corresponding beam angles.
- Beam Parameters:**
 - Beam 1 Angle: 90.0 degrees
 - Beam 2 Angle: 180.0 degrees
 - Beam 3 Angle: 270.0 degrees
- Treatment Time:**
 - Total: 152
 - Elapsed: 0
 - Remaining: 152
 - 0 %
- Plan and Machine:**
 - Plan type: 100%
 - Fraction Number: 18
 - Fraction Primary Dose: 0.00
 - Patient Orientation: 0.0
 - Gantry Angle: 60.0°
 - Couch Extens: 0.0
 - Couch Vertical: -9.0
 - Actual: 60.0°
 - Target: 60.0°

Delivery Evaluation - Example

ArcCheck - QA Plan Generation



Delivery Evaluation - Example

ArcCheck - QA Plan Generation

Patient

NEW BREAST, R SL, CASE 5

Left breast L up

MRN

DOB

Diagnosis

Fraction

Site

at Breast

T N M

New DV/21 IMRT Cont ArcCheck Plan

Position

System Status

Treatment Not Enabled

• MRI Ready

• RT Ready

• Couch Ready

• Gantry Ready

• Services Ready

Doors Fully Closed

RTCS Interlock

Beam On Button

IBC 61217 Compliant

Jun 18 2013 10:02PM

Dose (Gy)	Mean	Min	Max
Phantom Boundary	15.22	0.30	60.36
Isocenter	22.01	22.01	22.01

Calculate Dose

Without Magnetic Field

With Magnetic Field

Calculate and Display Dose

Compare To:

breast right
Created: 01/17/2013 09:46
Modified: 03/24/2013 09:27
Registration: Contours

Breast R AL
Created: 01/21/2013 12:18
Modified: 03/06/2013 16:06
Registration: Contours

IMRT breast MBW
Created: 03/24/2013 09:33
Modified: 06/24/2013 12:16

Delivery Workflow Options

Plan to Setup Image Registration Type:

Rigid

Deformable

Display

Group 1: Isocenter

240.0° Optimized Conformal

Total Beam-On: 257.75 sec Segments: 1

Fraction Beam-On: 10.31 sec

0.0° IMRT

Total Beam-On: 384.87 sec Segments: 13

Fraction Beam-On: 15.39 sec

Group 2: Isocenter

255.0° IMRT

Total Beam-On: 720.10 sec Segments: 10

Fraction Beam-On: 28.80 sec

15.0° IMRT

Total Beam-On: 545.71 sec Segments: 15

Fraction Beam-On: 21.83 sec

Group 3: Isocenter

30.0° Optimized Conformal

Total Beam-On: 175.09 sec Segments: 1

Fraction Beam-On: 7.00 sec

270.0° IMRT

Total Beam-On: 817.10 sec Segments: 14

Fraction Beam-On: 32.68 sec

Finalize

Approve Plan

Go To Delivery Calendar

DICOM
dose
distribution

- Gamma parameters
- Gamma passing rate under absolute dose
- RD – Relative
- AD - Absolute

Descriptive file
name

Improvement of
Gamma passing
rate with
calculated shift

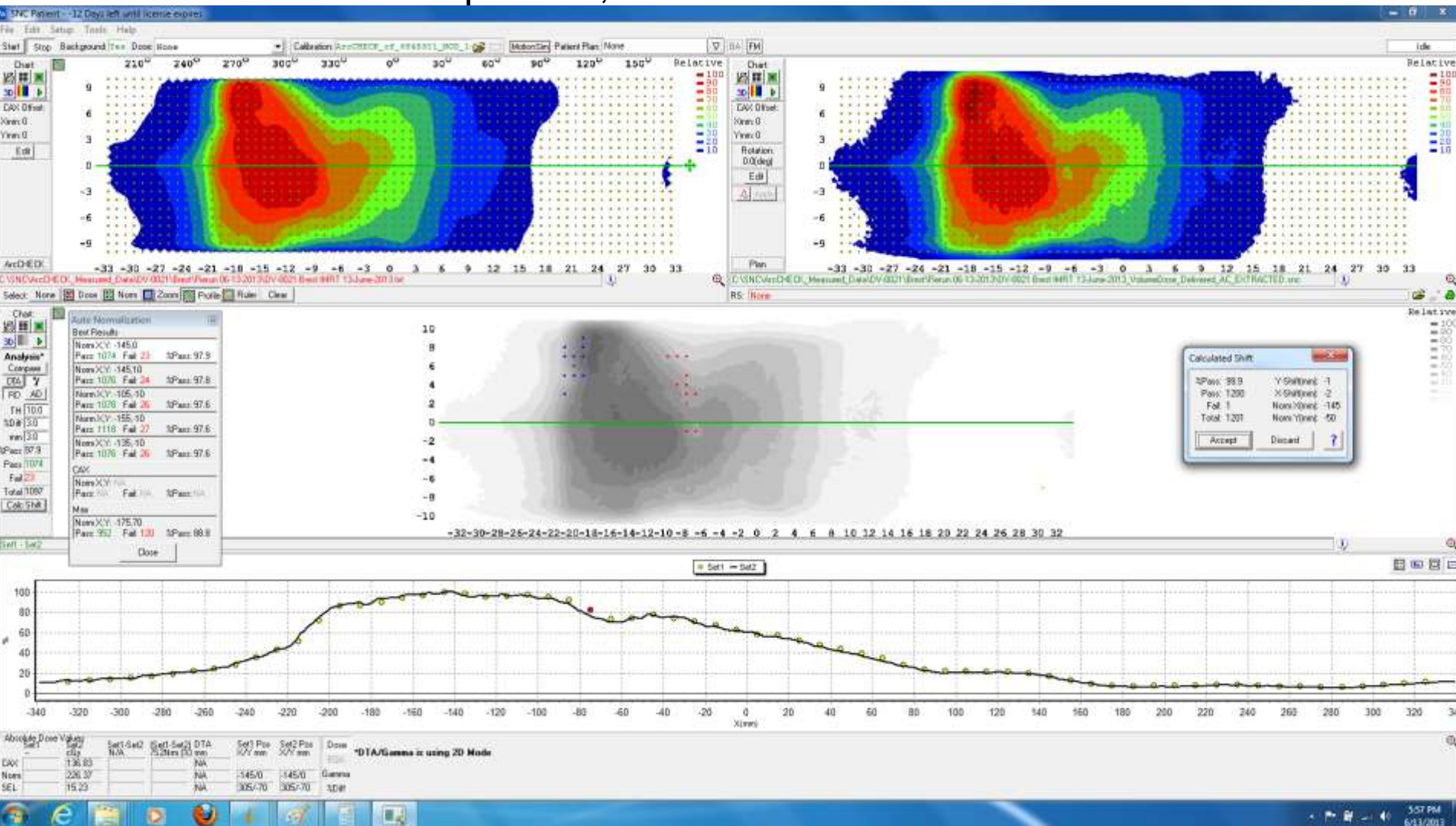
Gamma
passing at
different
normalization
points for
relative dose
comparison

Profile across
the green line

Hot & cold spots overlaid on
DICOM planned dose distribution

Delivery Evaluation - Example

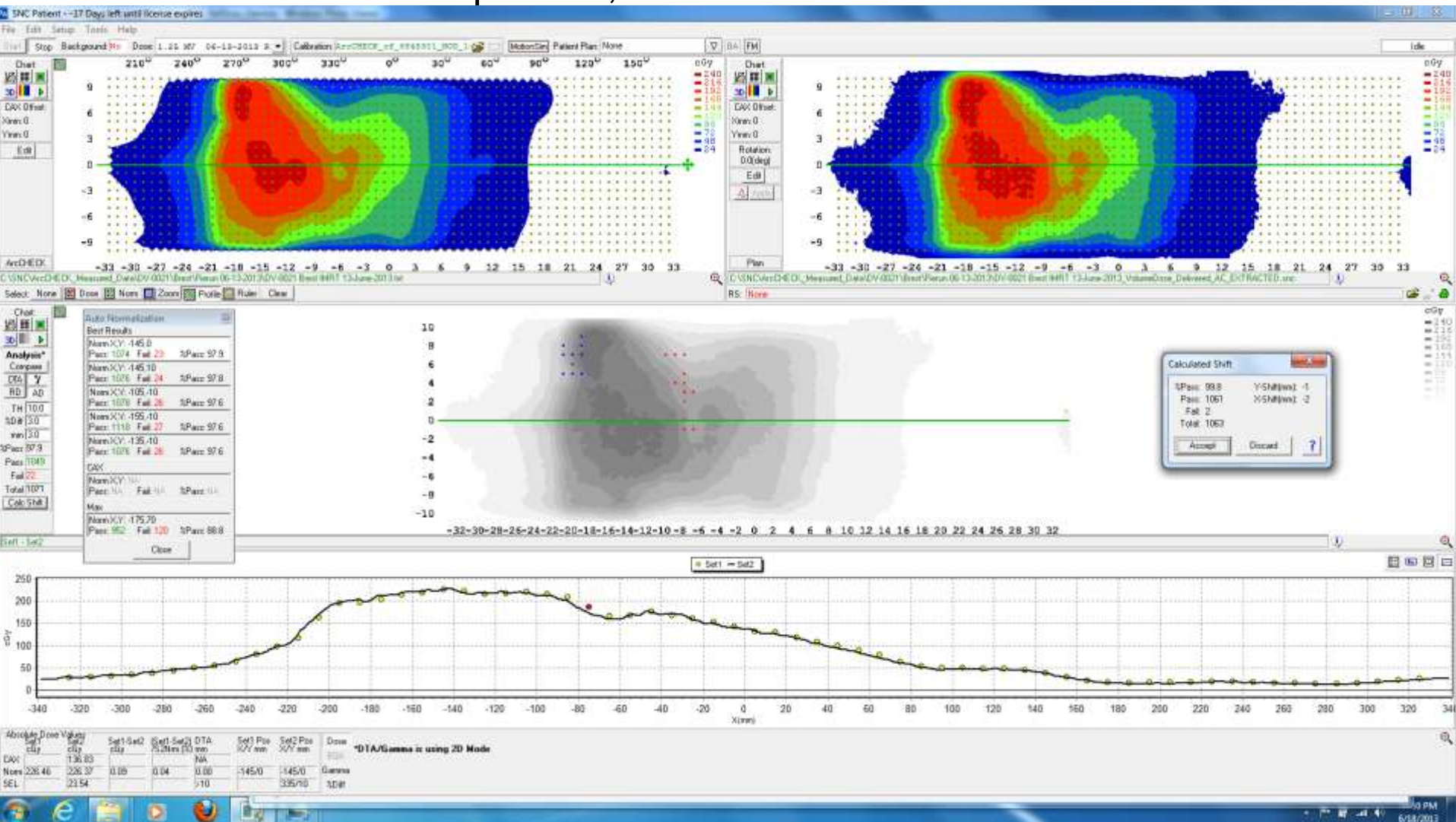
Relative Dose Comparison, ArcCheck Measured vs. DICOM



Gamma(3mm, 3%, 10% dose threshold) 98% passing rate

Delivery Evaluation - Example

Absolute Dose Comparison, ArcCheck Measured vs. DICOM



Gamma(3mm, 3%, 10% dose threshold) 98% passing rate

Does organ motion matter?



Int. J. Radiation Oncology Biol. Phys., Vol. 76, No. 3, Supplement, pp. S135–S139, 2010

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0360-3016/10/\$–see front matter

doi:10.1016/j.ijrobp.2009.06.093

QUANTEC: VISION PAPER

ACCURATE ACCUMULATION OF DOSE FOR IMPROVED UNDERSTANDING OF RADIATION EFFECTS IN NORMAL TISSUE

DAVID A. JAFFRAY, PH.D.,* PATRICIA E. LINDSAY, PH.D.,* KRISTY K. BROCK, PH.D.,*
JOSEPH O. DEASY, PH.D.,[†] AND W. A. TOMÉ, PH.D.[‡]

From the *Radiation Medicine Program, Princess Margaret Hospital, Department of Radiation Oncology, University of Toronto, Toronto, Ontario, Canada; [†]Department of Radiation Oncology, Washington University, St. Louis, MO; and [‡]Departments of Human Oncology and Medical Physics, University of Wisconsin School of Medicine and Public Health, Madison, WI

The actual distribution of radiation dose accumulated in normal tissues over the complete course of radiation therapy is, in general, poorly quantified. Differences in the patient anatomy between planning and treatment can occur gradually (e.g., tumor regression, resolution of edema) or relatively rapidly (e.g., bladder filling, breathing motion) and these undermine the accuracy of the planned dose distribution. Current efforts to maximize the therapeutic ratio require models that relate the true accumulated dose to clinical outcome. The needed accuracy can only be achieved through the development of robust methods that track the accumulation of dose within the various tissues in the body. Specific needs include the development of segmentation methods, tissue-mapping algorithms, uncertainty estimation, optimal schedules for image-based monitoring, and the development of informatics tools to support subsequent analysis. These developments will not only improve radiation outcomes modeling but will address the technical demands of the adaptive radiotherapy paradigm. The next 5 years need to see academia and industry bring these tools into the hands of the clinician and the clinical scientist. © 2010 Elsevier Inc.

Dose accumulation, Normal tissue effects, Deformation, Four-dimensional, Informatics.

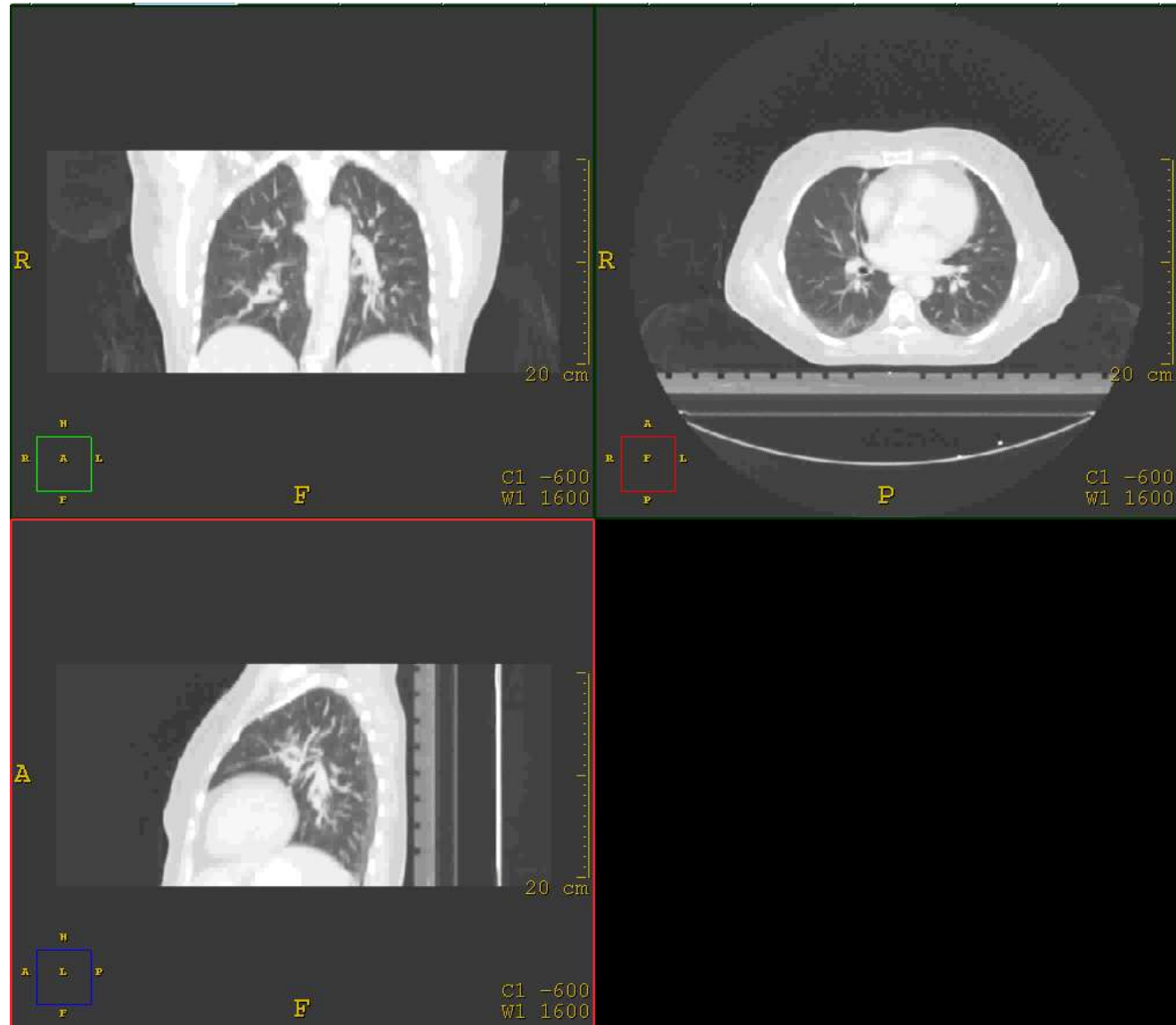
QUANTEC Vision Paper

“Accurately estimating D_A (true dose) is a critical element in the drive to maximize the performance and safe application of radiation therapy for the patient.

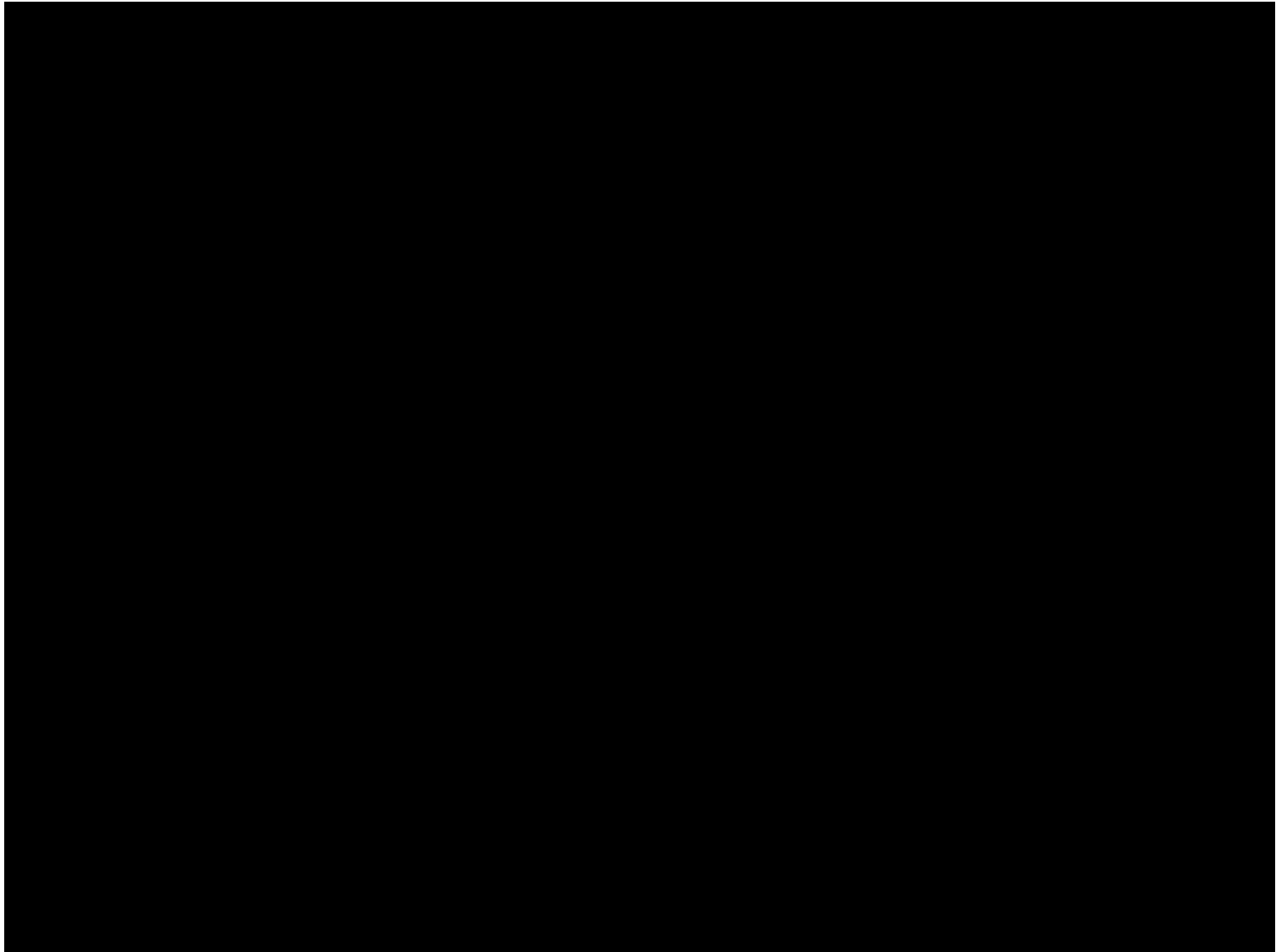
“It has thus been established that “planned dose” does not necessarily equal “delivered dose” for any given fraction or for the treatment as a whole. Moreover, changes in tumor and normal tissue during therapy suggest that the ultimate quantity of interest is D_A —particularly for normal tissues.”

Respiratory Motion Correlated CT (4DCT)

Approximately a single breath reconstructed from one to two minutes of data collection and played in a cine mode = approximation of a single breath of data



1vps – 5 minute movie of motion



A possible solution to QUANTEC vision

- D_A AvID – True Dose (D_A) Accumulation via Deformable Image Registration
 1. Record patient motion during delivery at 4vps (volumes per second)
 2. Calculate dose on individual volumes
 3. Accumulate individual volume doses to a common reference
 4. Do this for each fraction
- Proof of concept for 1vps, working on 4vps
- Seeking NIH funding

Thank you!

