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

ViewRay

- 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

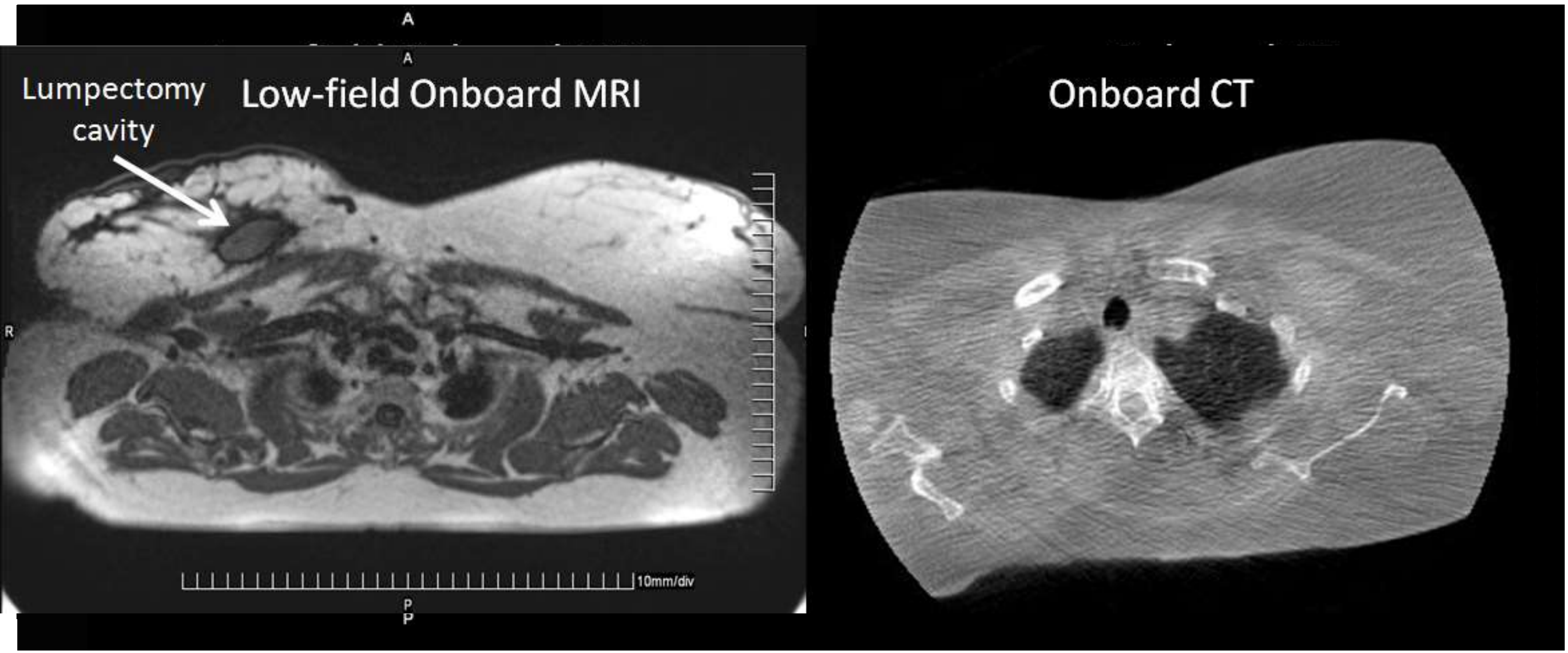
ViewRay

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

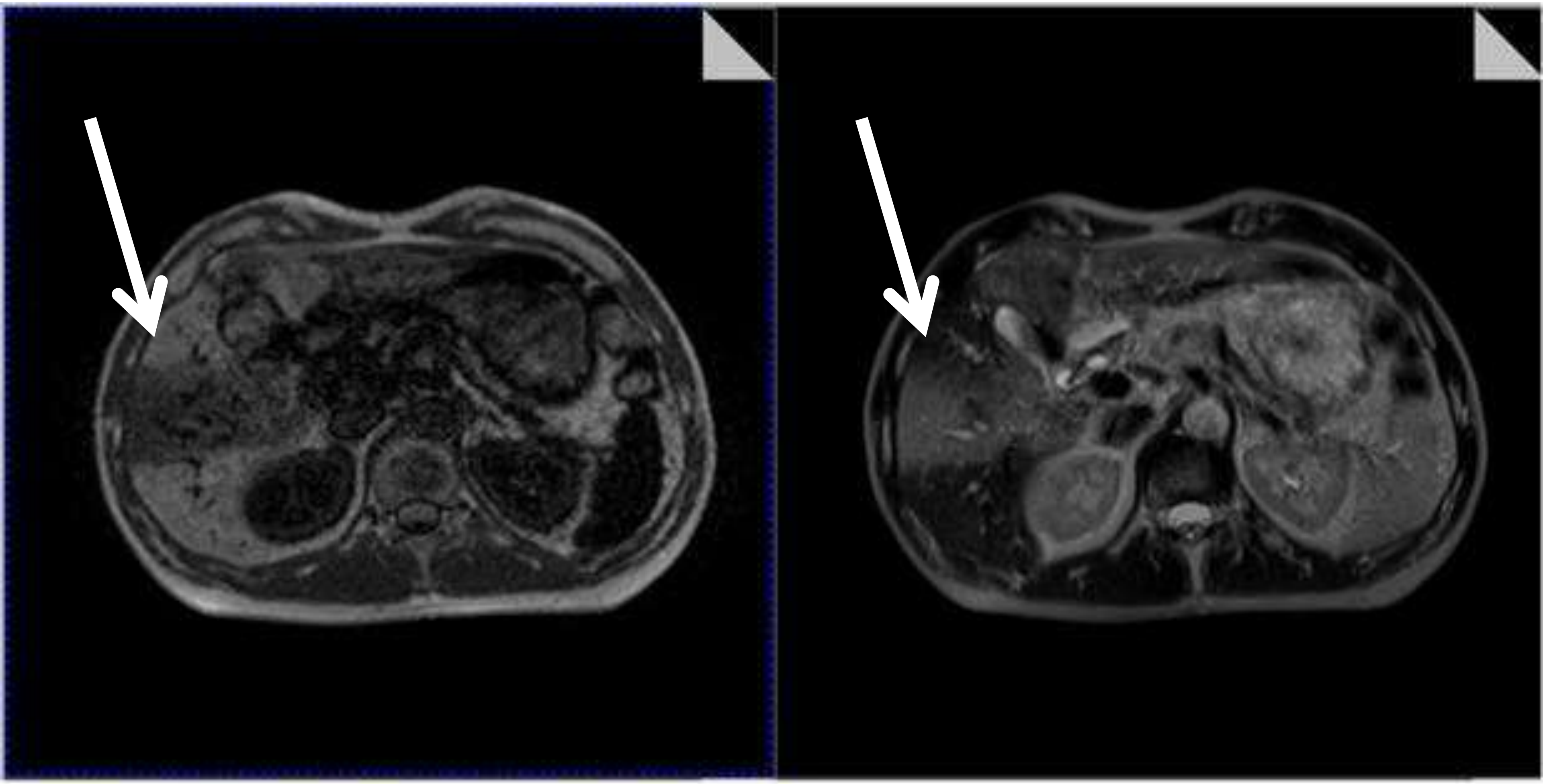


Washington University Study

Noelle, C. et. al., manuscript submitted

What else can we see with MR?

Radiation Damage - Edema

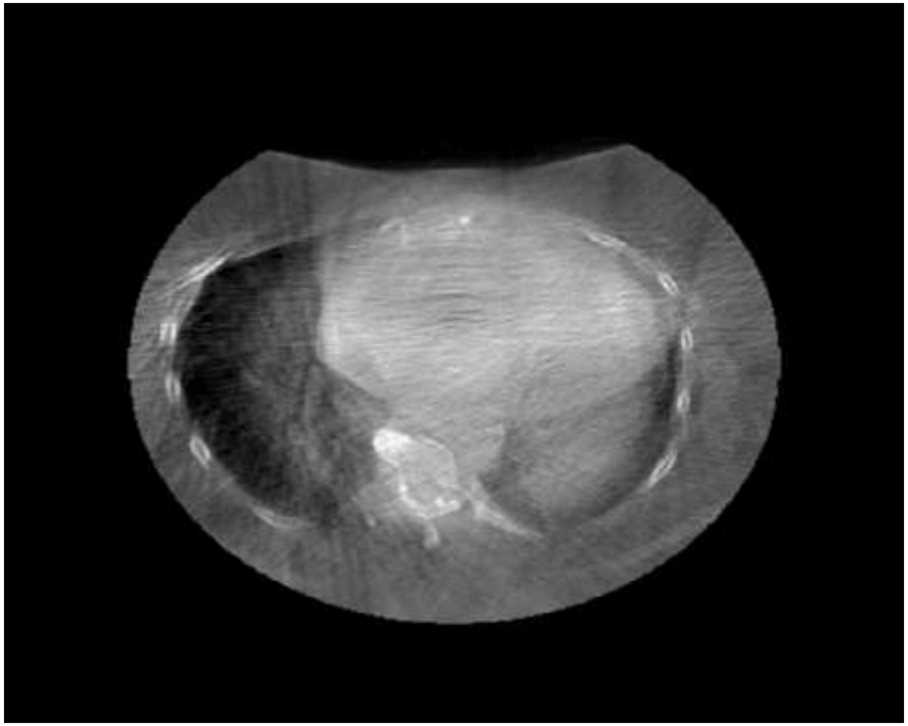


Washington University Study

Imaging system evaluation

Clinical study comparing 0.35T MR and CBCT

Onboard MR

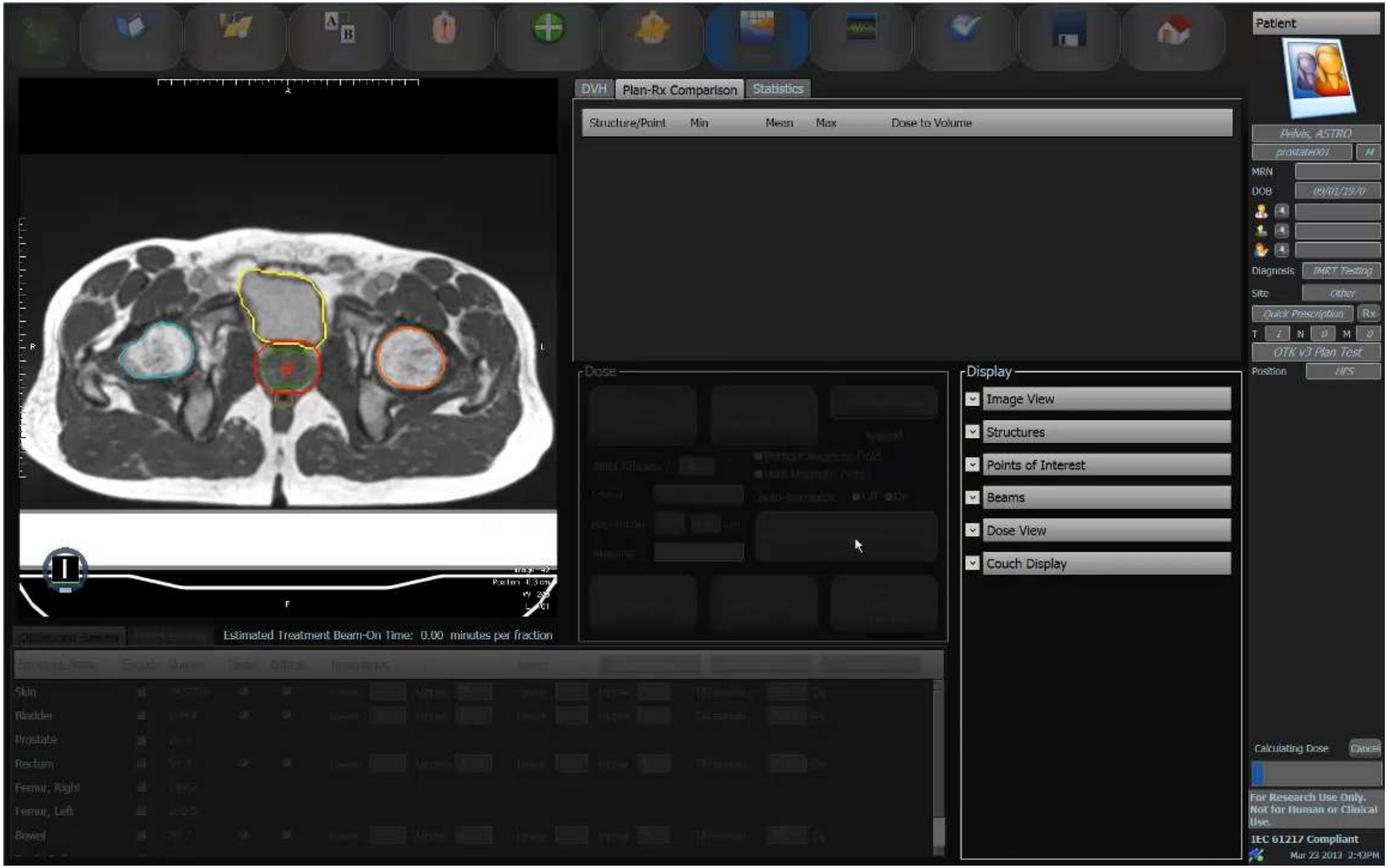


Onboard CT

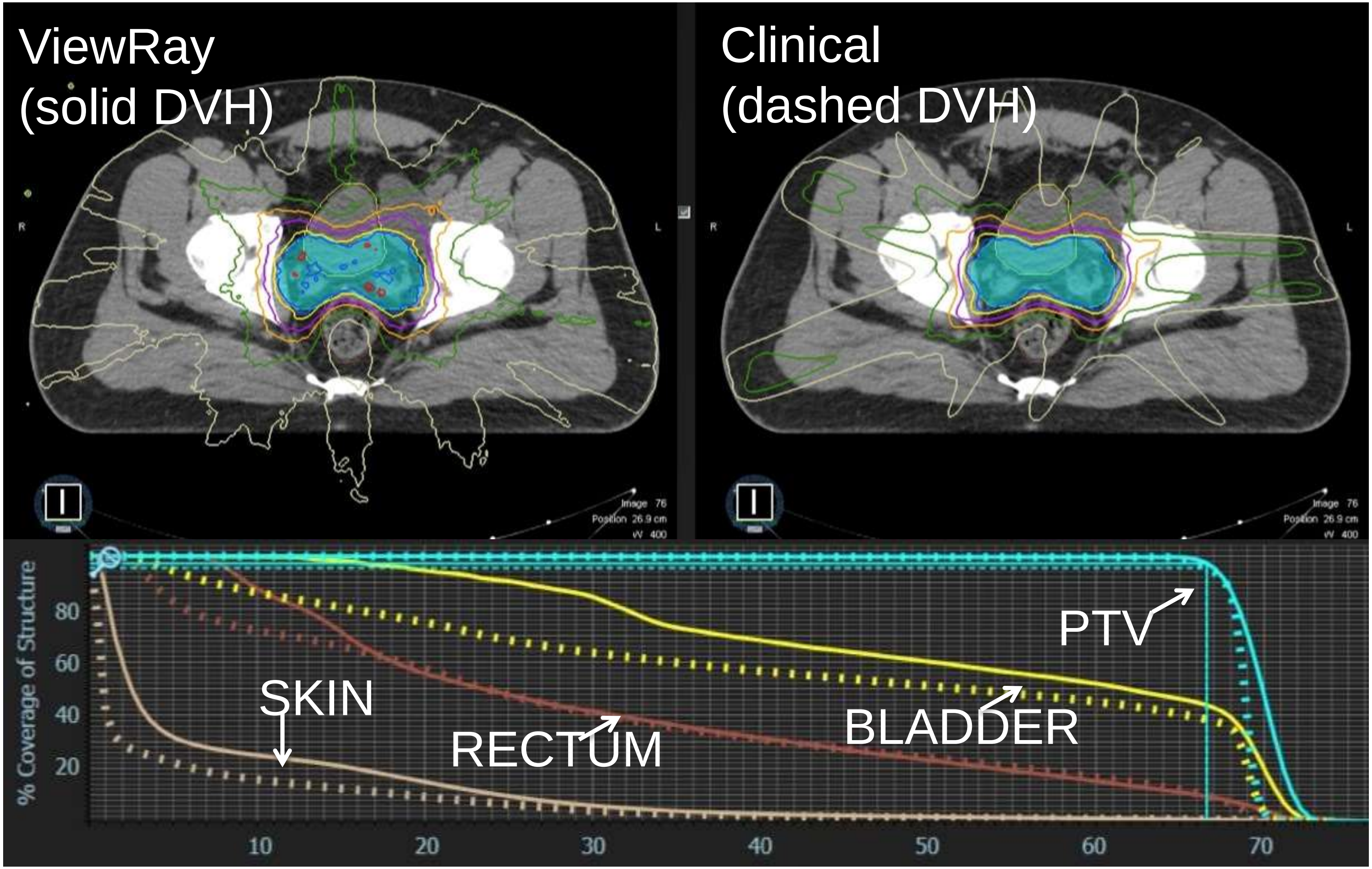
Treatment Planning System Evaluation

- Dedicated TPS
  - Integrated from prescription though 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

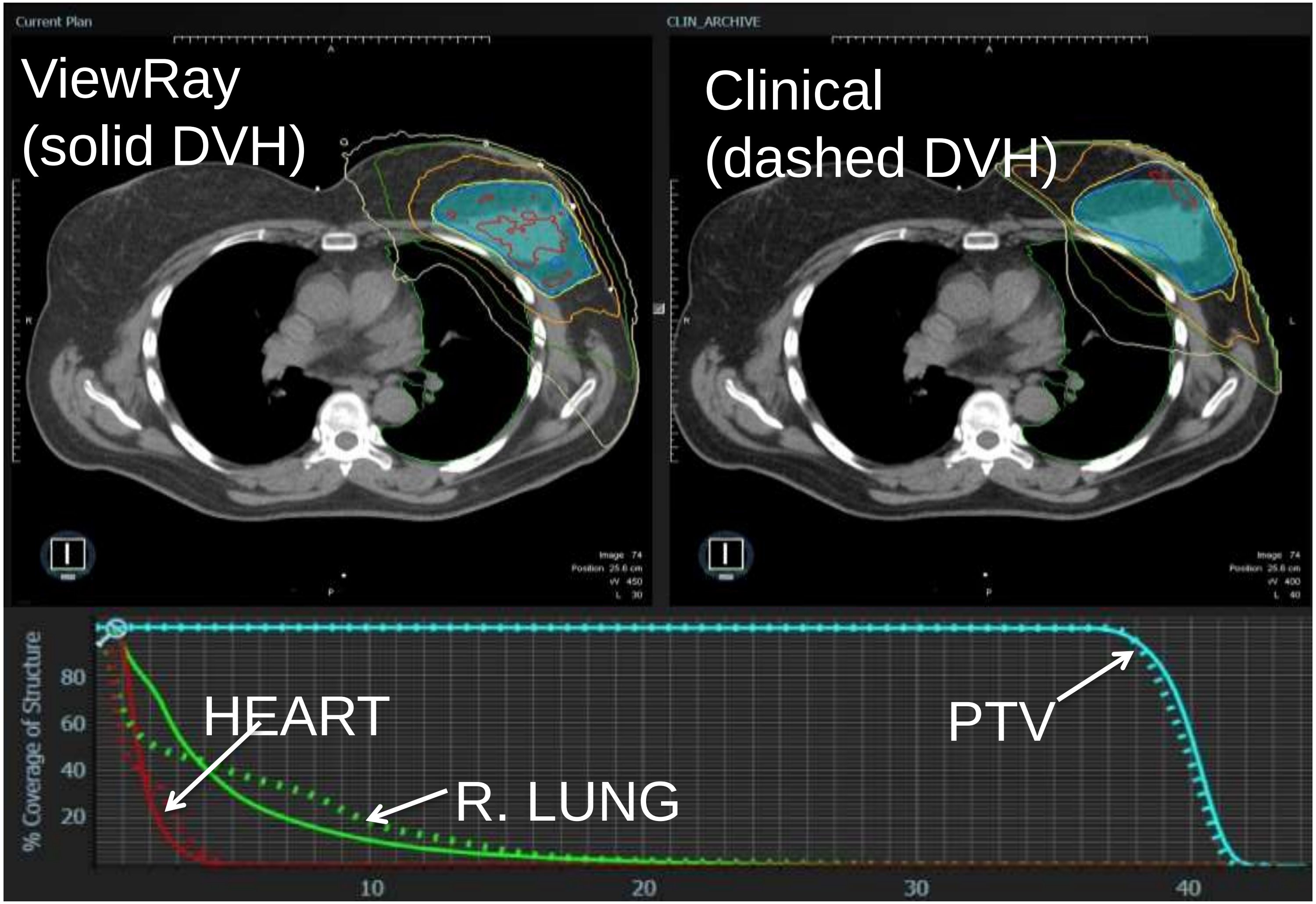


Treatment Planning System Evaluation



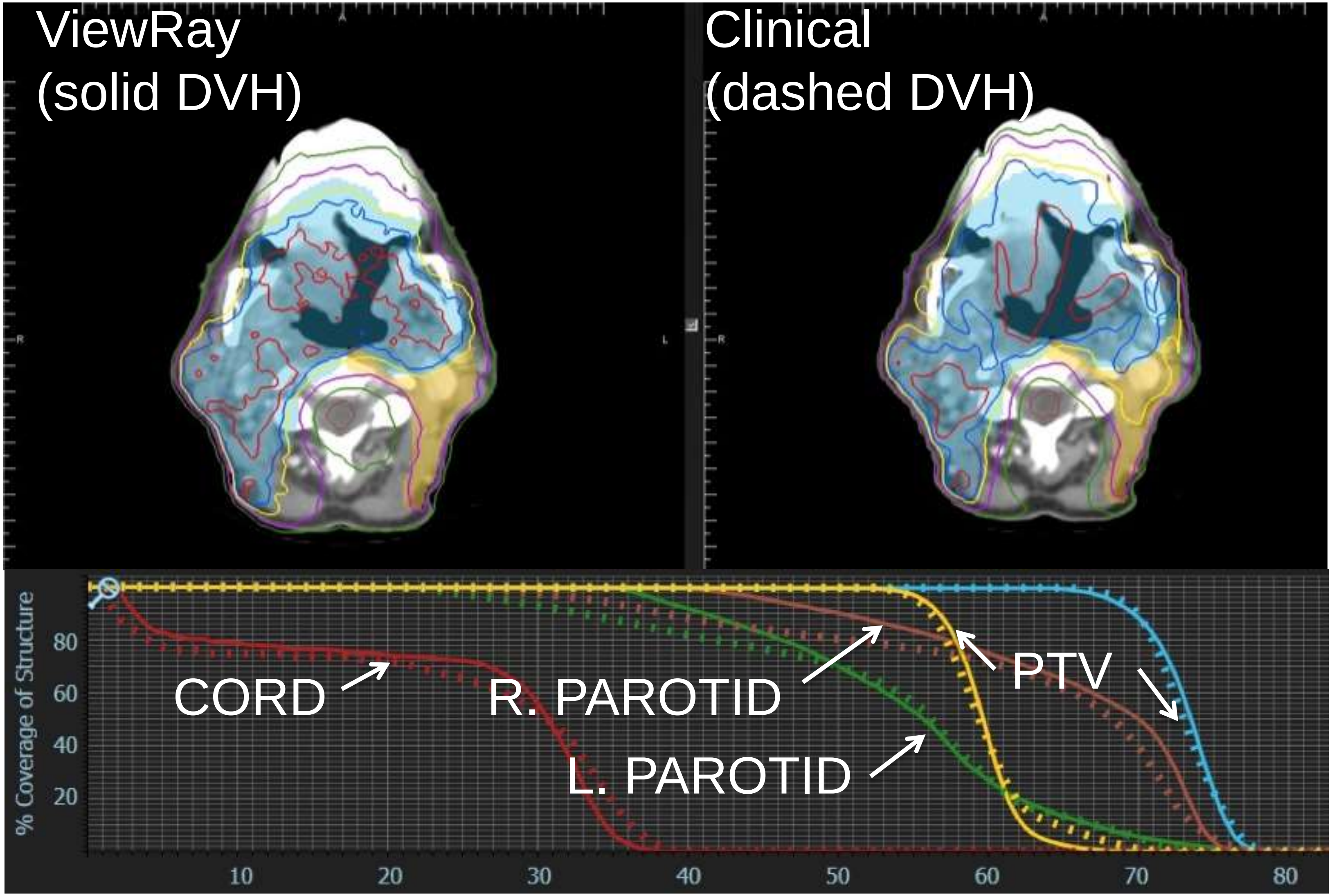
ViewRay: ^{60}Co IMRT **Clinical plan:** 18 MV IMRT

Treatment Planning System Evaluation



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

Treatment Planning System Evaluation



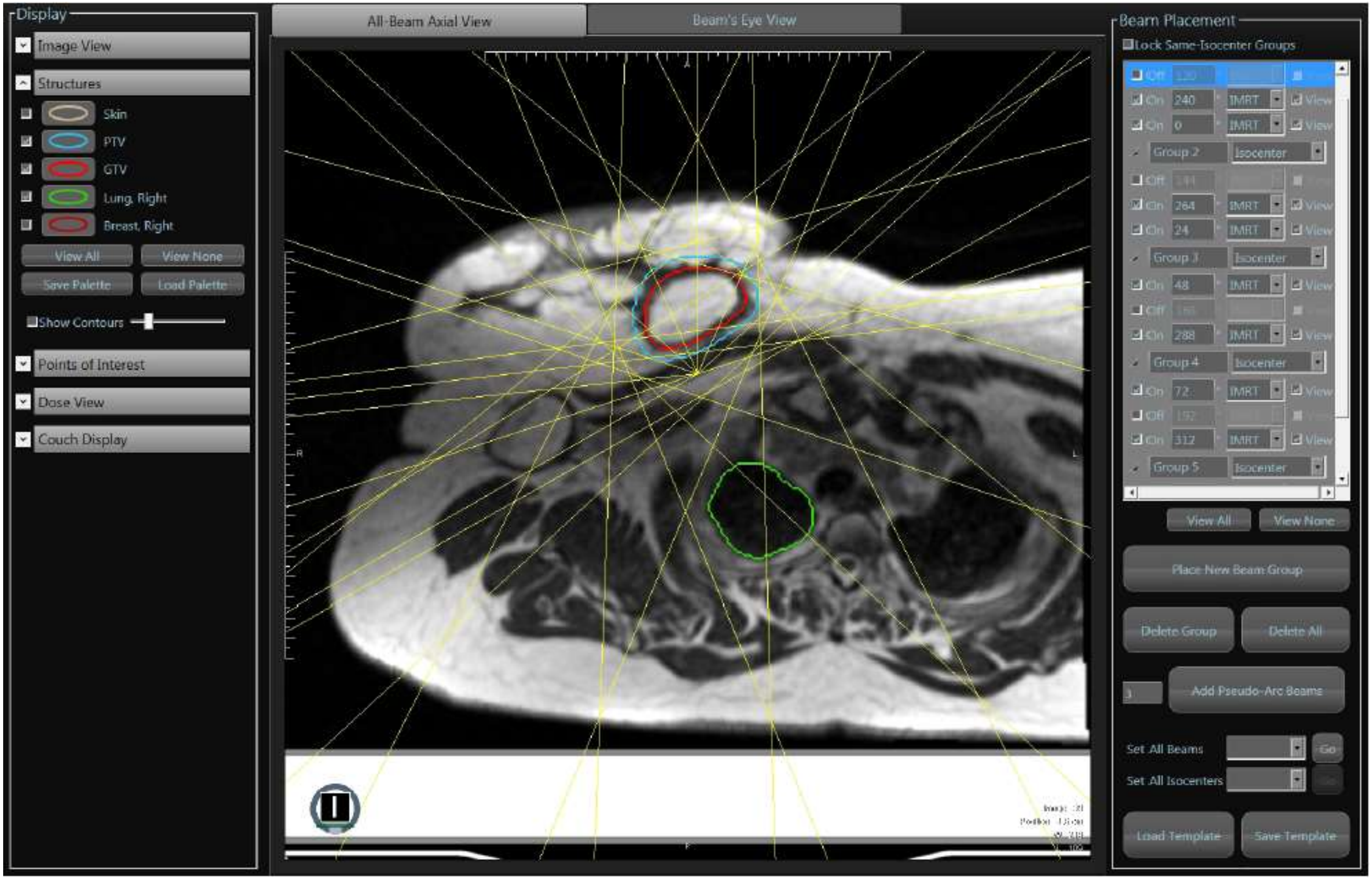
ViewRay: ^{60}Co IMRT **Clinical plan:** Definitive 6 MV IMRT

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 tolls 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

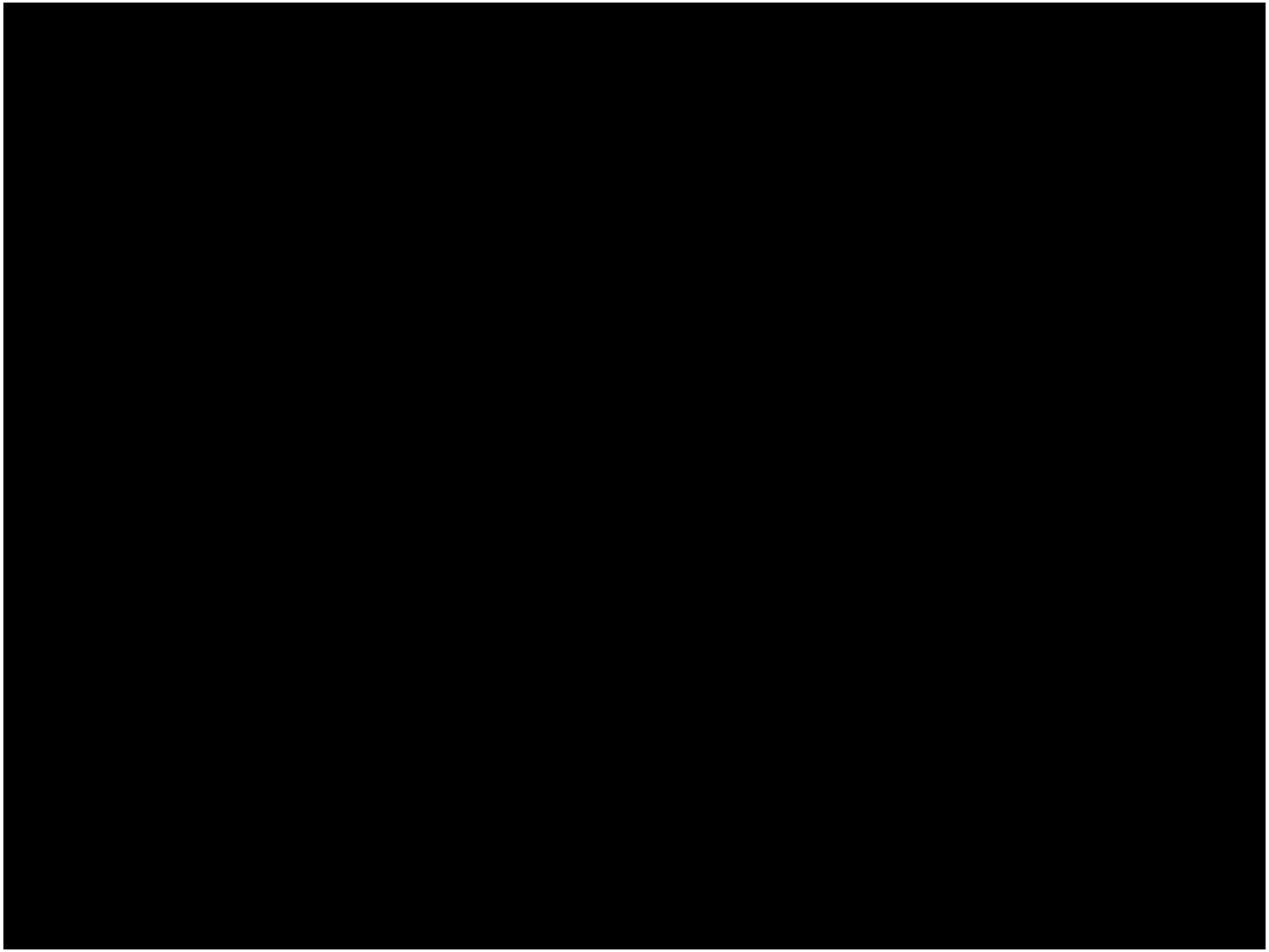
High res with contour propagation and deformation (as desired)

Workflow – Daily Dose Control

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

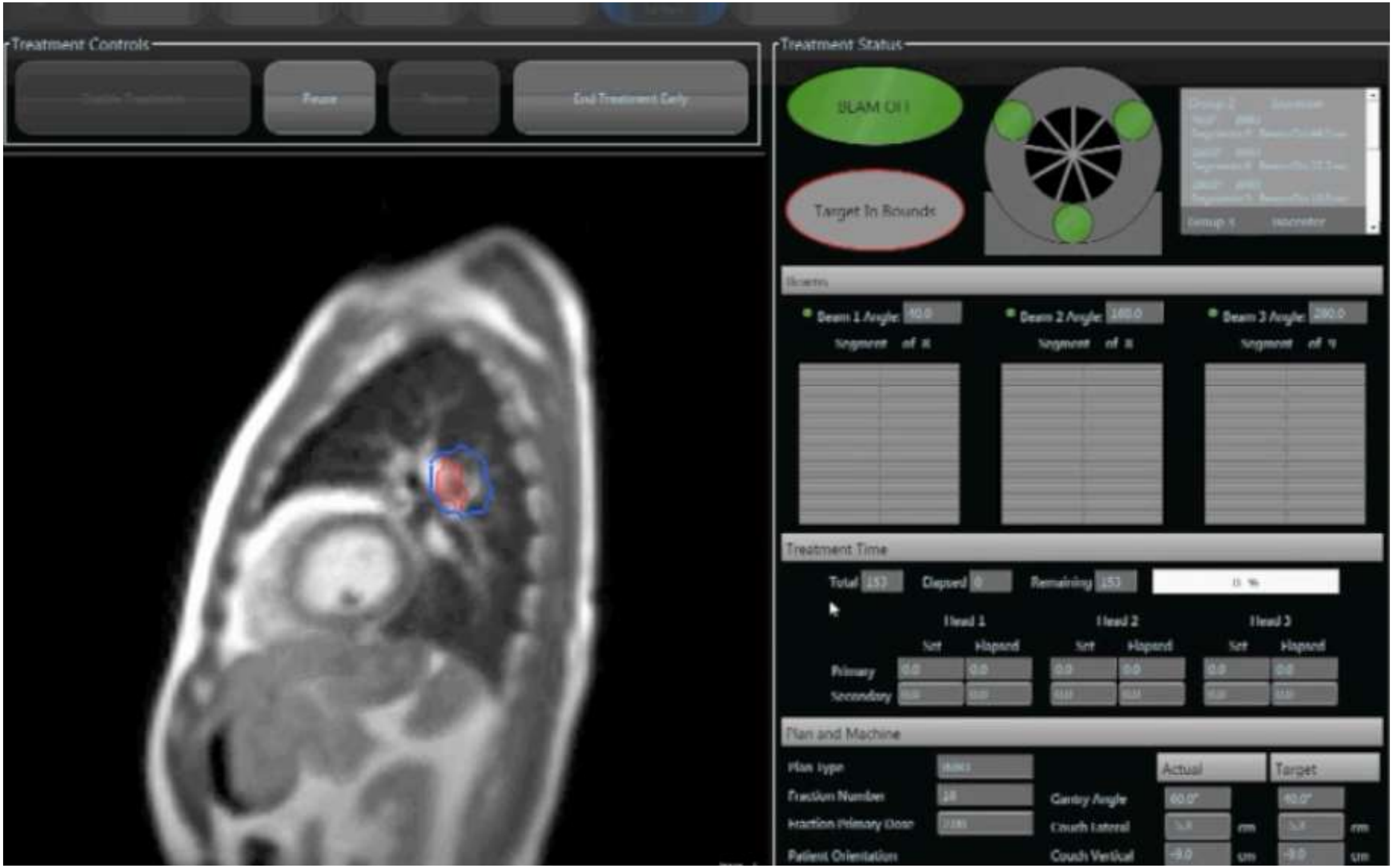
Workflow – MR Controlled Treatment

Fast imaging and real time target delineation



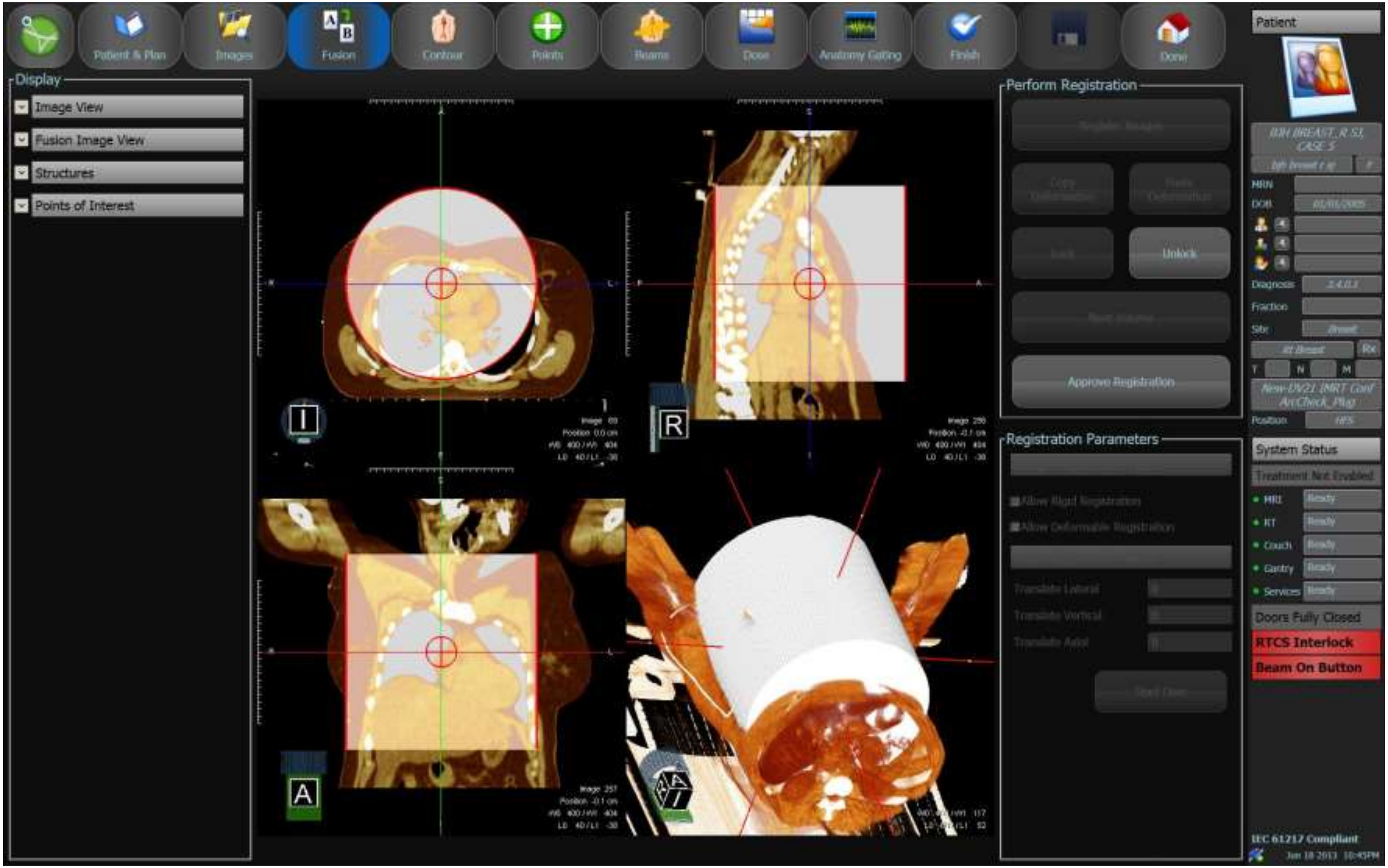
Workflow – MR Controlled Treatment

Fast imaging and real time target delineation



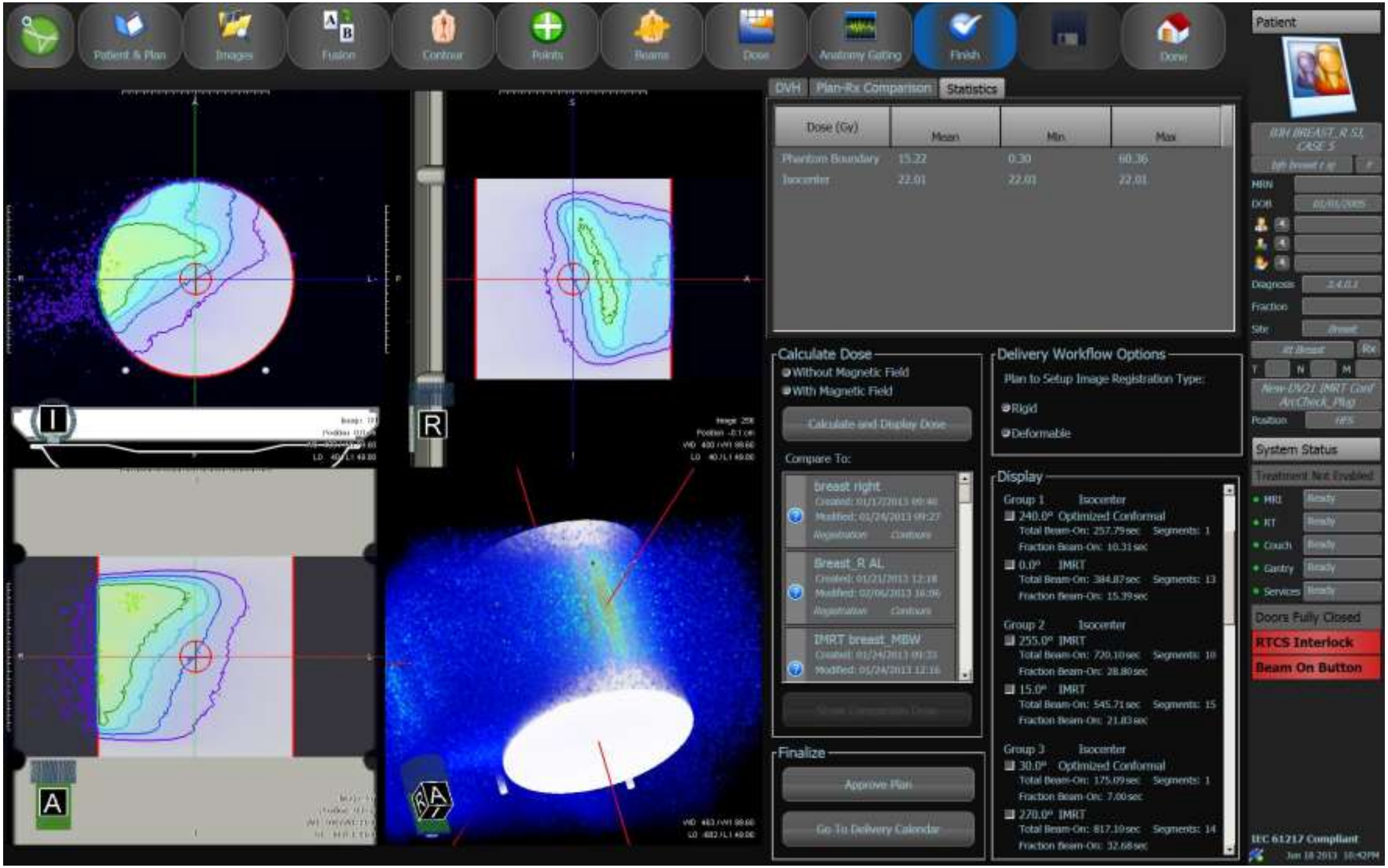
Delivery Evaluation - Example

ArcCheck - QA Plan Generation



Delivery Evaluation - Example

ArcCheck - QA Plan Generation

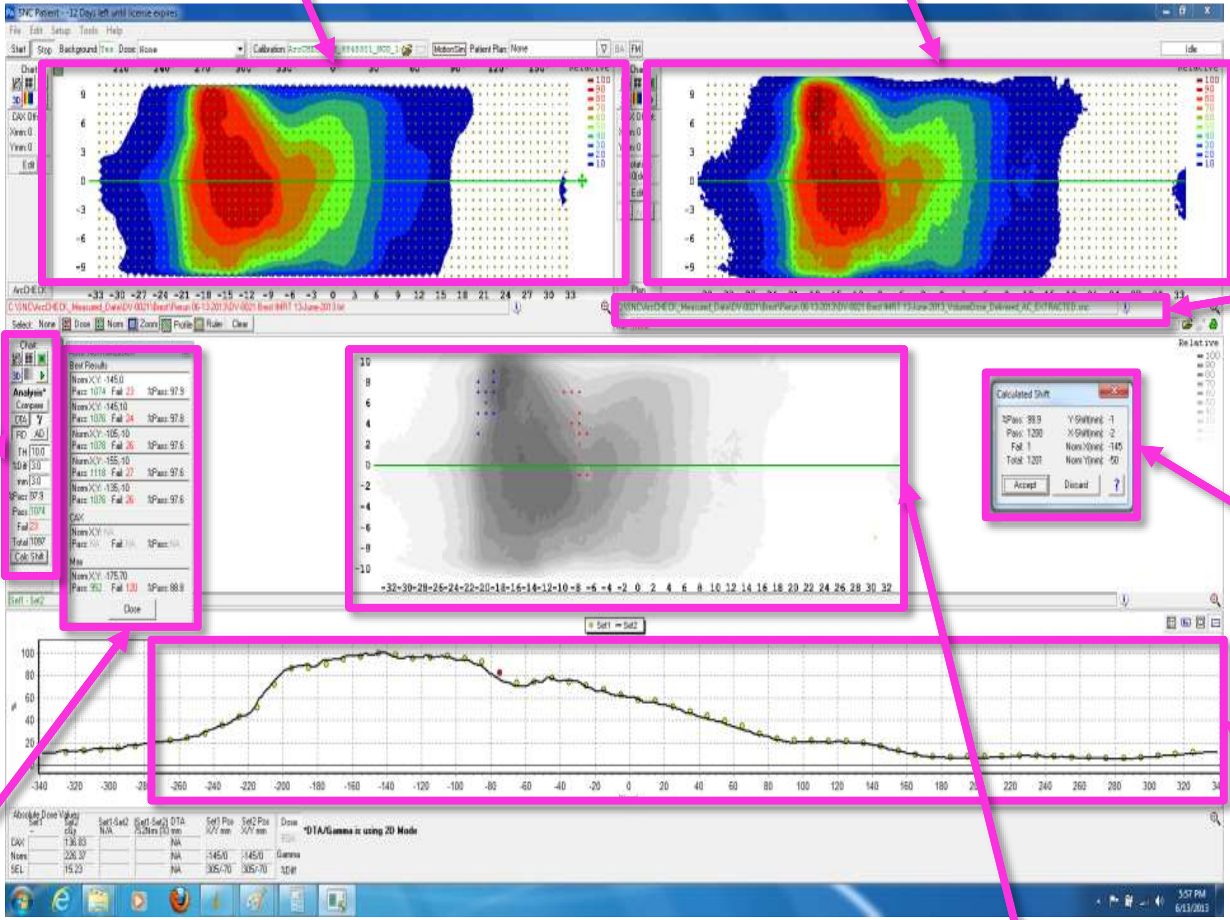


Key to ArcCheck Patient Analysis Window

ArcCHECK measured dose distribution

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

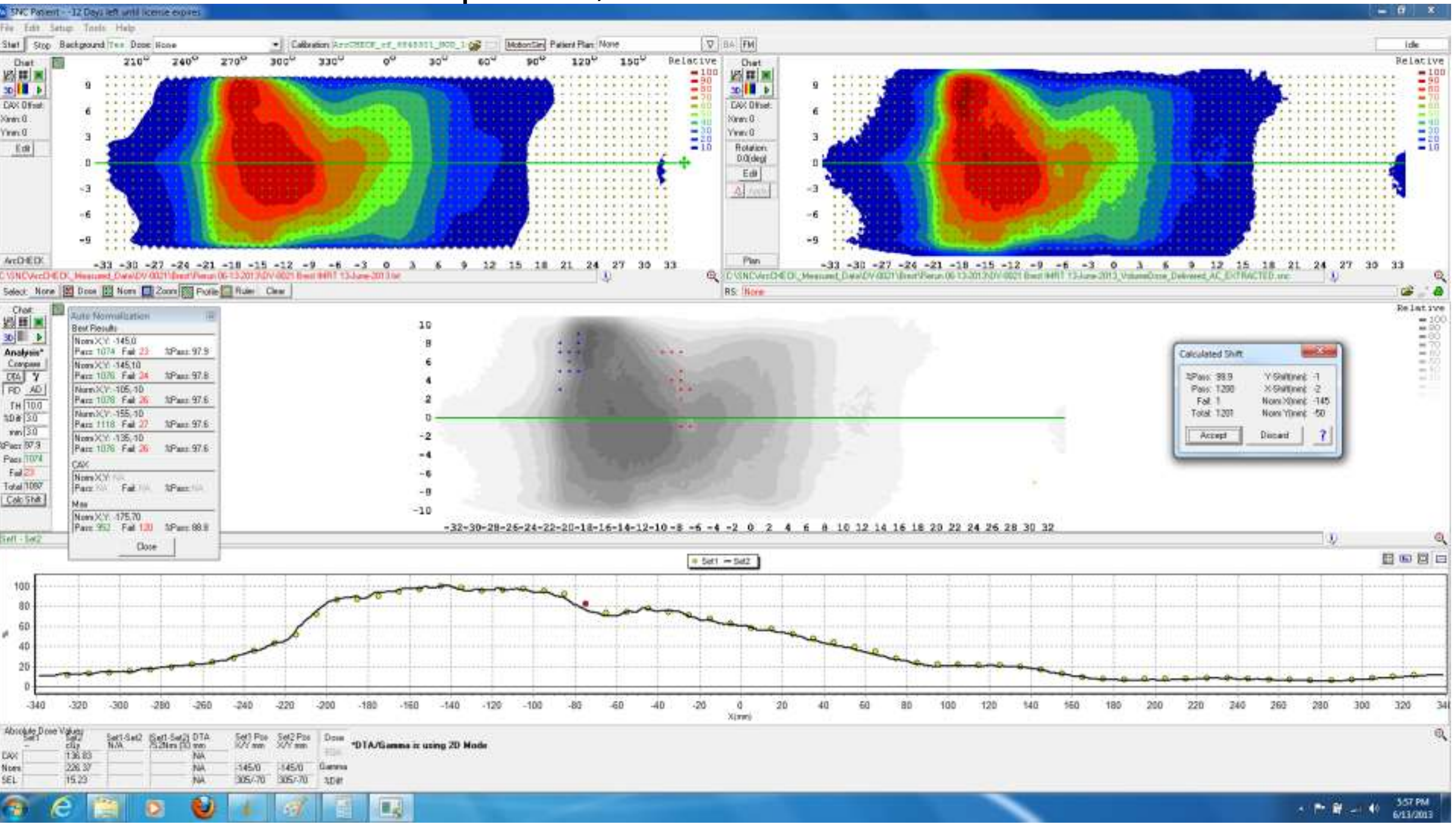
Gamma passing at different normalization points for relative dose comparison

Profile across the green line

Hot & cold spots overlaid on DICOM planned dose distribution

Delivery Evaluation - Example

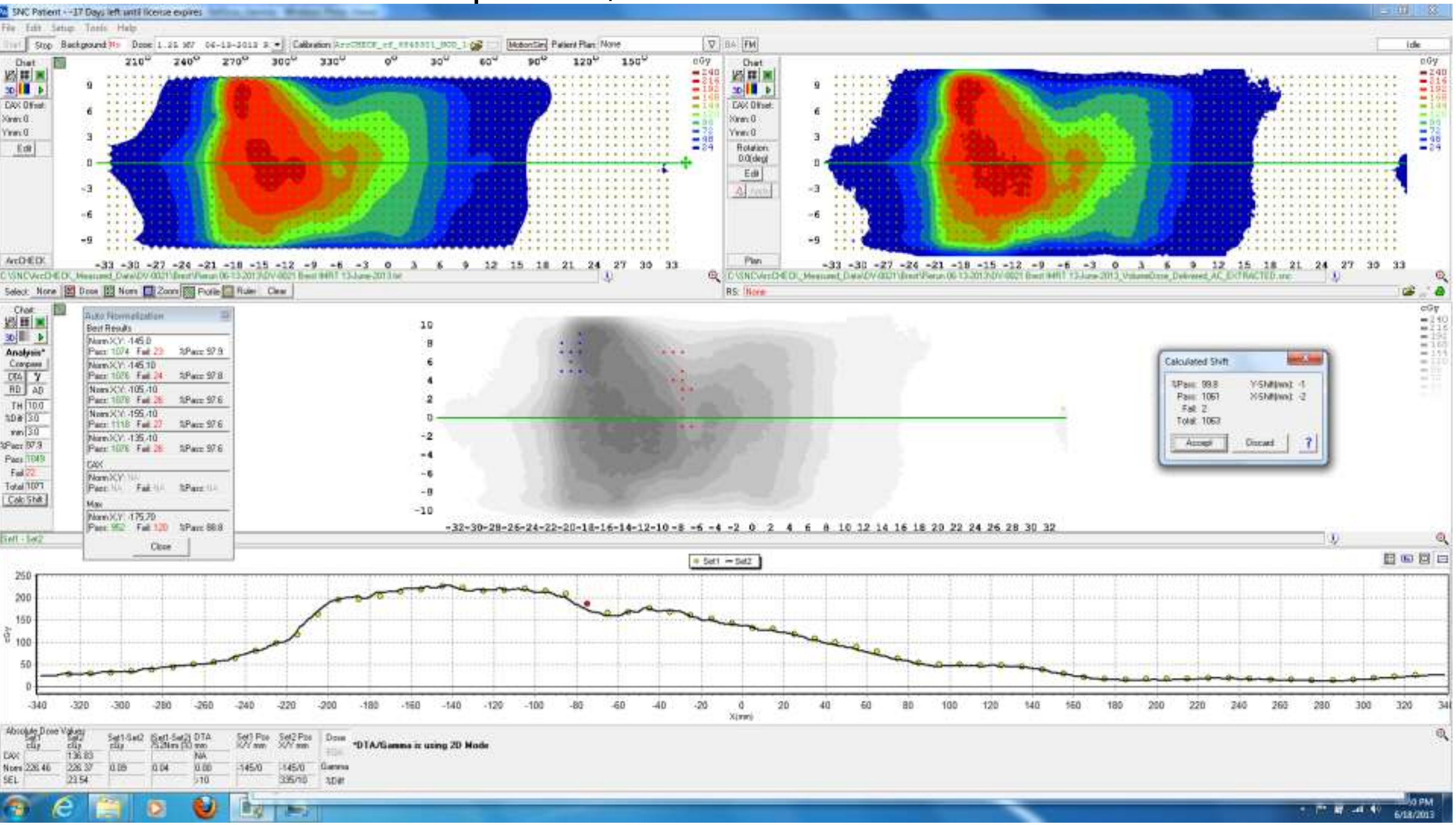
Relative Dose Comparison, ArcCheck Measured vs. DICOM



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

ELSEVIER

doi:10.1016/j.ijrobp.2009.06.093

QUANTEC: VISION PAPER

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

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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.

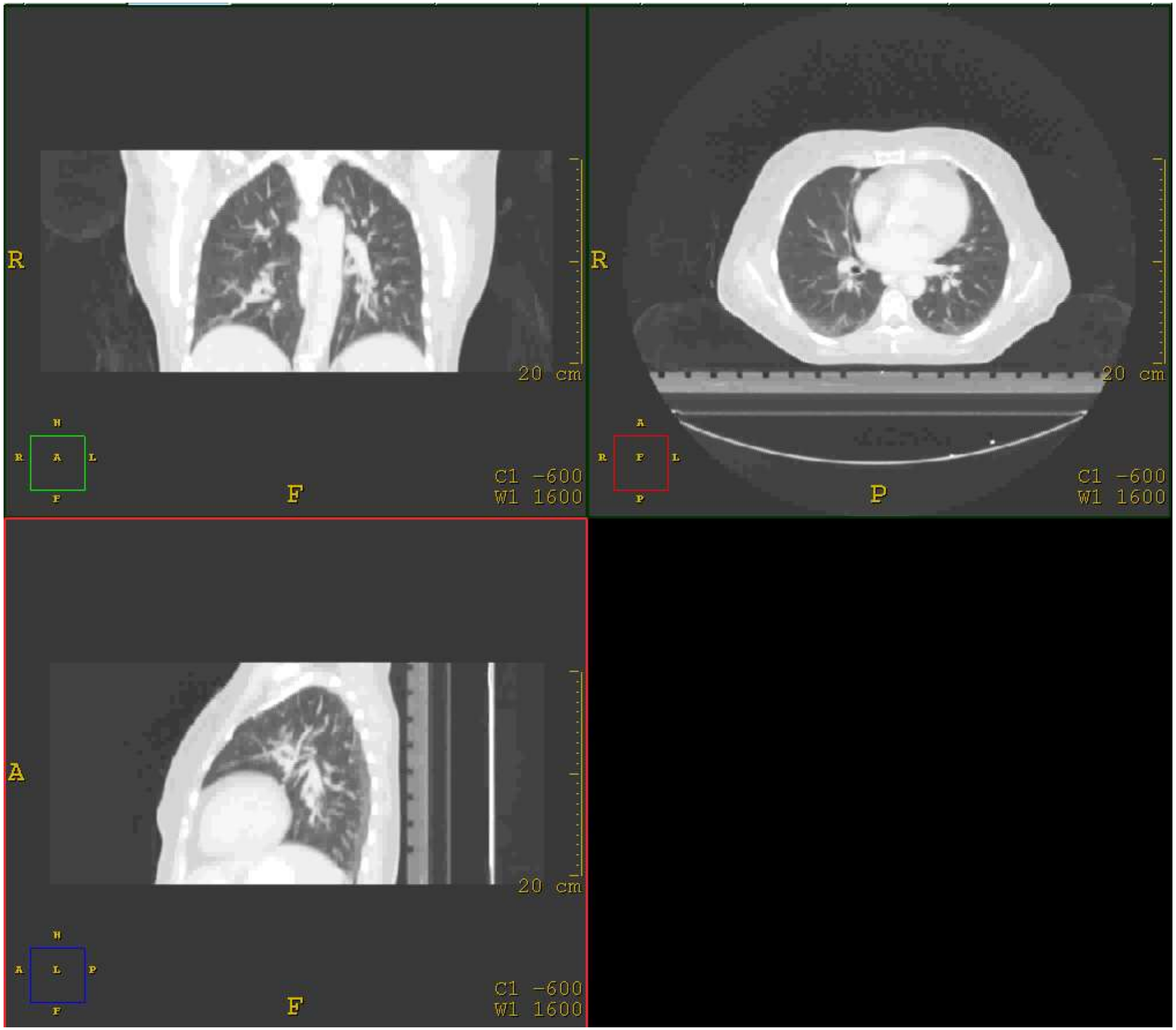
QUANTEC Vision Paper

"*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*.

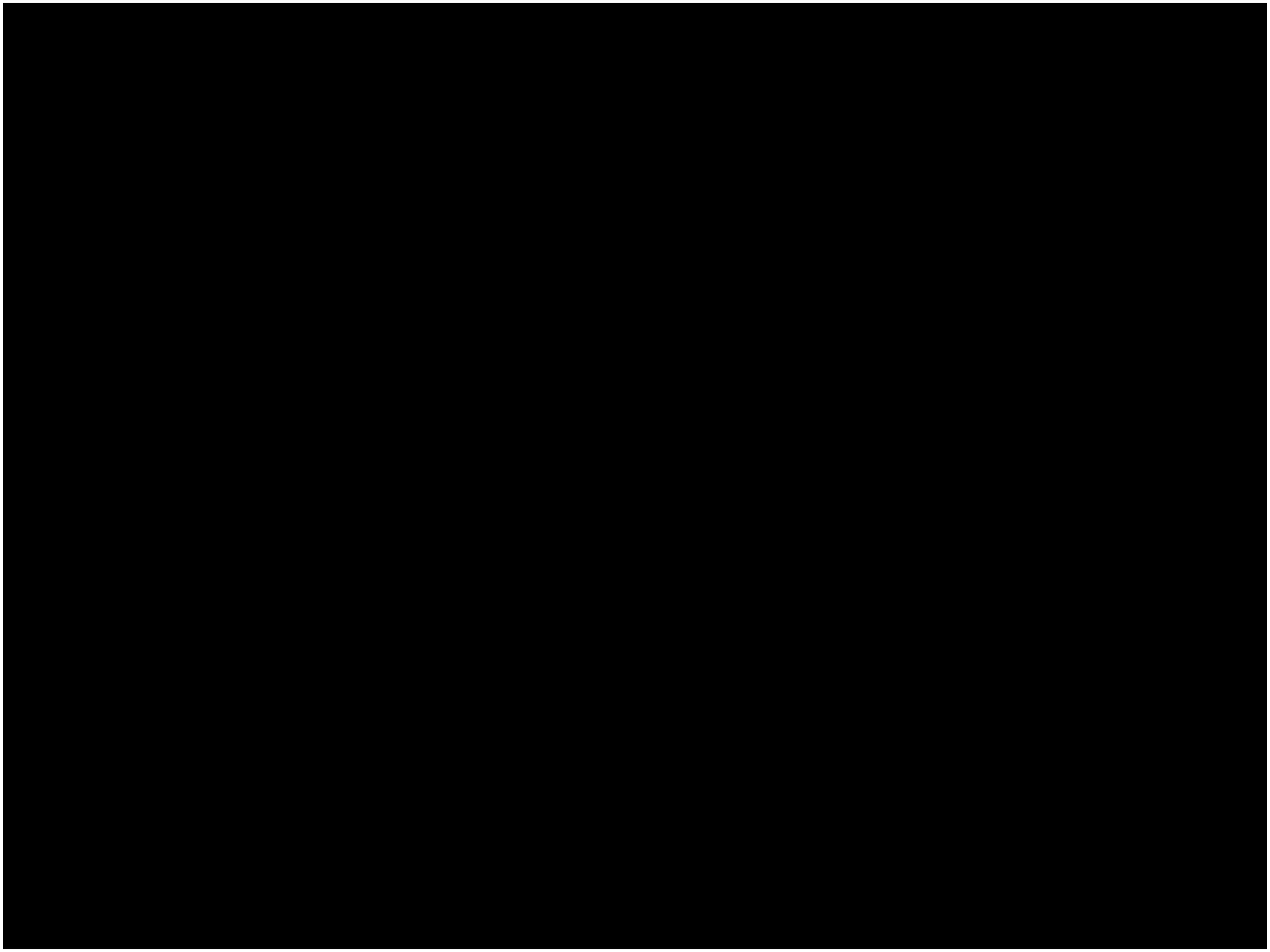
"It has thus been established that "planned dose" does not necessarily equal "delivered dose" for any given fraction or for the treatment as a whole. Moreover, changes in tumor and normal tissue during therapy suggest that the ultimate quantity of interest is D_A—particularly for normal tissues."

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_AA*v*ID – 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!