Development of an Independent Audit Device for Remote Verification of 4D Radiotherapy

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RPC Radiological Physics Center
Excellence through Quality Assurance

THE UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER

Introduction

- Radiation therapy of thoracic and abdominal tumors is complicated by respiratory induced motion
- Larger margins are required around target volumes to account for intra-fractional movement
- Margin reduction can lead to decreased dose to normal tissue and allow for target dose escalation and improved local tumor control

Introduction

- Margin reduction accomplished primarily by explicitly accounting for respiratory motion
  - Internal target volume (ITV)
  - Gating
- 4D techniques require a quality assurance device
  - Equipment acceptance and commissioning
  - Dosimetric verification of treatment plans
- The Radiological Physics Center (RPC) requires an independent audit device for 4D protocols

Objectives

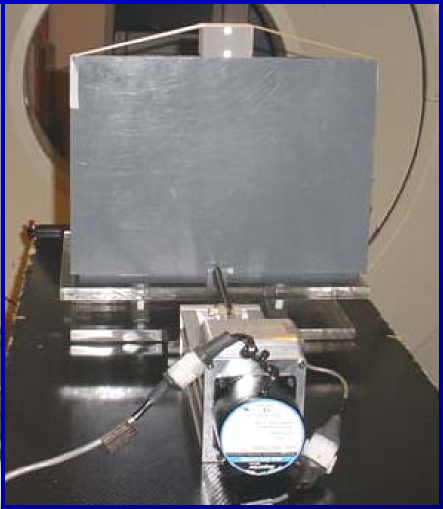
- Develop and build a quality assurance (QA) system that simulates respiratory induced motion
- Image the QA system along with the RPC anthropomorphic lung-thorax phantom
- Irradiate the QA system and assess dose delivery

Development of a QA system to simulate respiratory motion

- Motion extents derived from literature
- Typical sinusoidal human respiratory pattern was modeled.
- Assume correlated motion between external surfaces and internal tumor motion.
- Use a two plate design for simplicity and rigidity.

Results (Development)

- Phantom QA System Construction
  - Custom software developed for creation and storage of respiratory patterns
  - Simple, stand-alone operation with robust design suitable for travel
  - Modify original design to accommodate CT field of view size limitations



Results (Development)

- Phantom QA System Construction

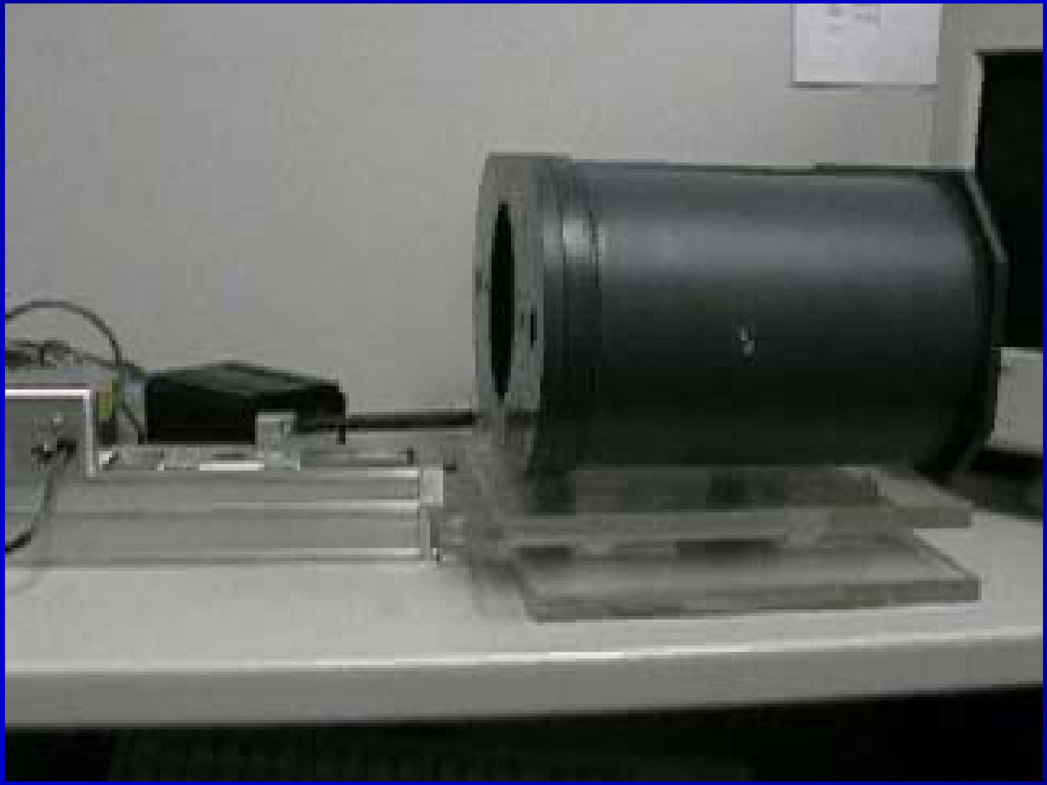
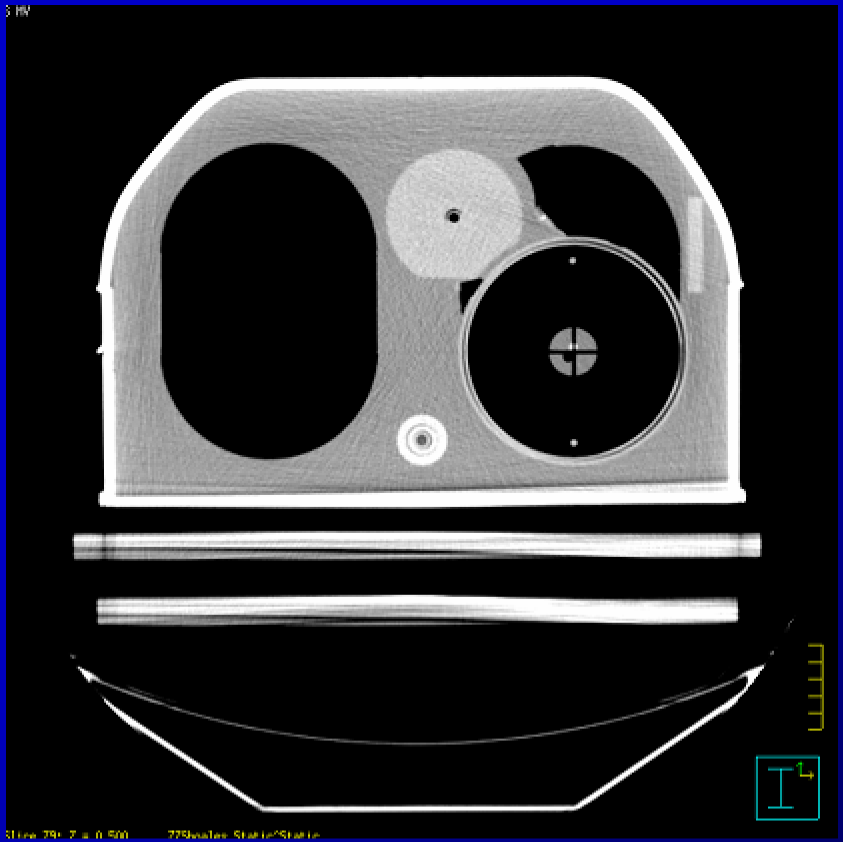


Image QA System along with RPC Thorax-lung Phantom

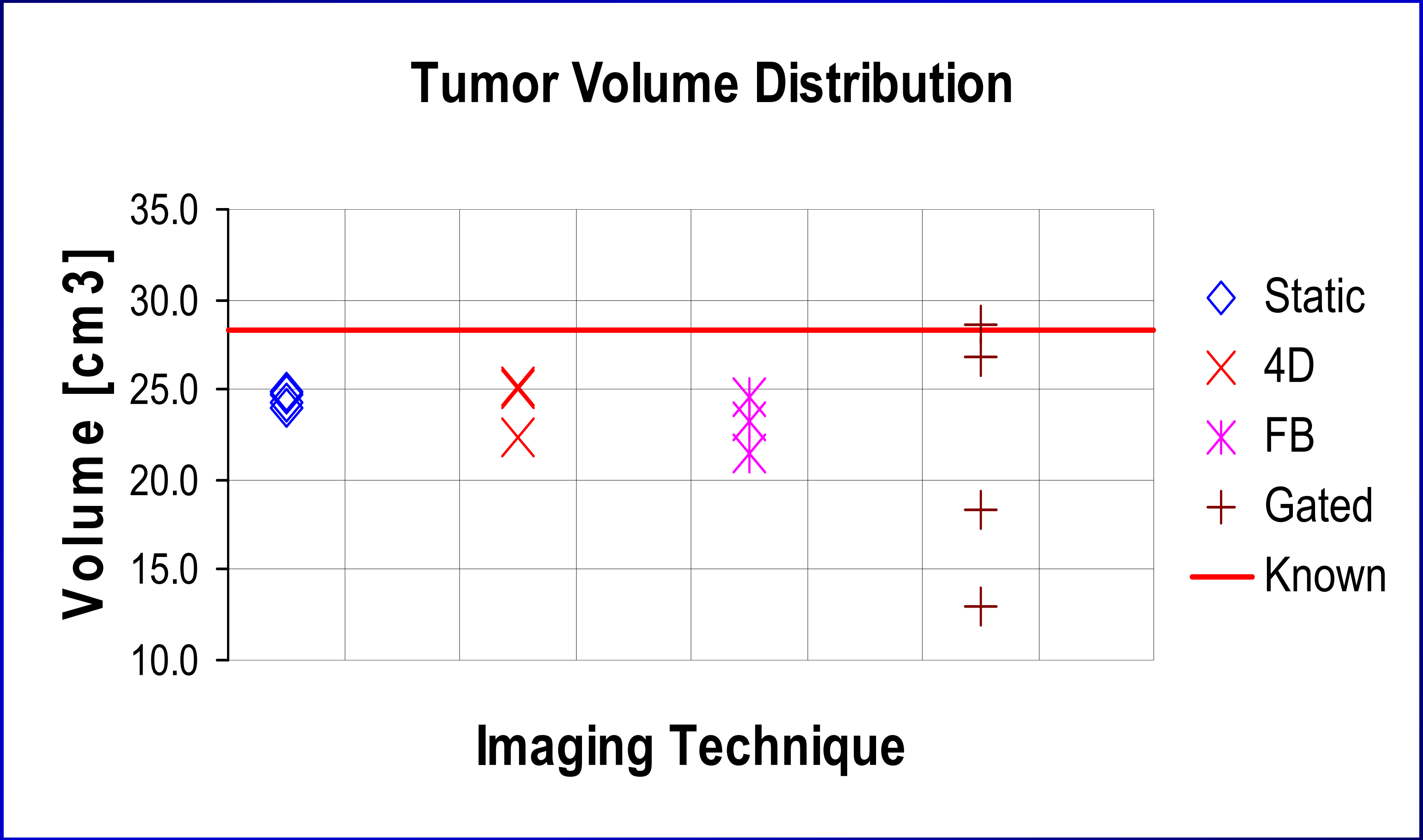
- Anthropomorphic phantom containing simulated heart, spine, lung and tumor.
- Acquire static,breath-hold, free-breathing, gated and 4D CT datasets.
- Assess imaging reproducibility by measuring internal structure volumes
- Clinically constrained treatment plans



Results (Imaging)

- Imaging Reproducibility
  - Qualitative agreement with known tumor volumes for static, BH, 4D, free-breathing and gated CT acquisitions
  - Reproducibility decreased with motion while gating demonstrated the largest range of volumes
  - Central axial diameter of the tumor shows greatest tumor shape distortion with gated datasets

Results (Imaging)



Results (Treatment Planning)

- Techniques
  - Static
  - Free-breathing ITV
  - Gated
- Treatment Plans
  - Clinically constrained prescriptions
  - Three fields, 6 MV
  - 20 Gy prescription for at least 95% PTV coverage
  - Pinnacle^3 (v. 6.2b) used

Dosimetric Evaluation of the Phantom QA System

- Dosimeters
  - TLD's
    - absolute dose in tumor (superior and inferior), heart, and cord.
  - Radiochromic Film
    - 2D dose distributions (axial, sagittal, coronal).
    - Isodose comparisons, binary agreement maps and profile analysis.
  - Dosimetry reproducibility evaluation
    - Static technique used as baseline, 3 trials each for free-breathing ITV and gated.
- Criteria
  - ±5% or 3mm distance to agreement (TG-53)

Results (Dosimetry)

- Dosimetry Assessment
  - High level of agreement with calculated values for all TLD measurements (within 1% for all techniques at the tumor location)
  - Excellent agreement shown at the ±5%/3mm level for axial, coronal and sagittal films for static and free-breathing ITV techniques.
  - Expected regions of disagreement in the beam penumbra for static and free-breathing ITV techniques.
  - Poor agreement outside the tumor volume for the gated technique

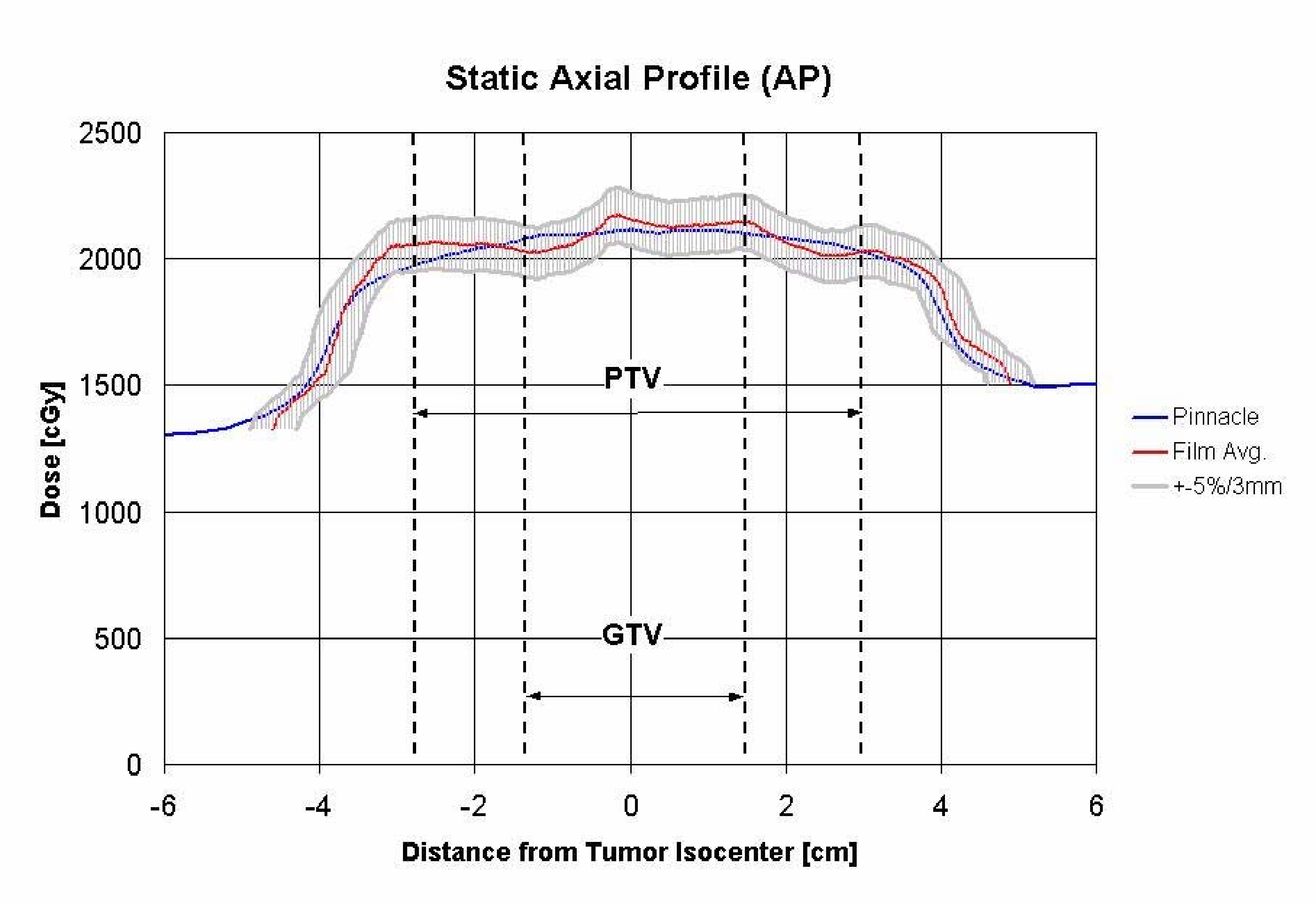
Results (Dosimetry)

TLD Results Summary (Dose values in cGy)

Technique	TLD	Pinnacle[3]	TLD/Pinnacle[3]
Static	2125.7	2102.4	1.011
Free-Breathing ITV	2142.7	2118.1	1.012
Gated	2114.7	2119.6	0.998

Results (Static Plan)

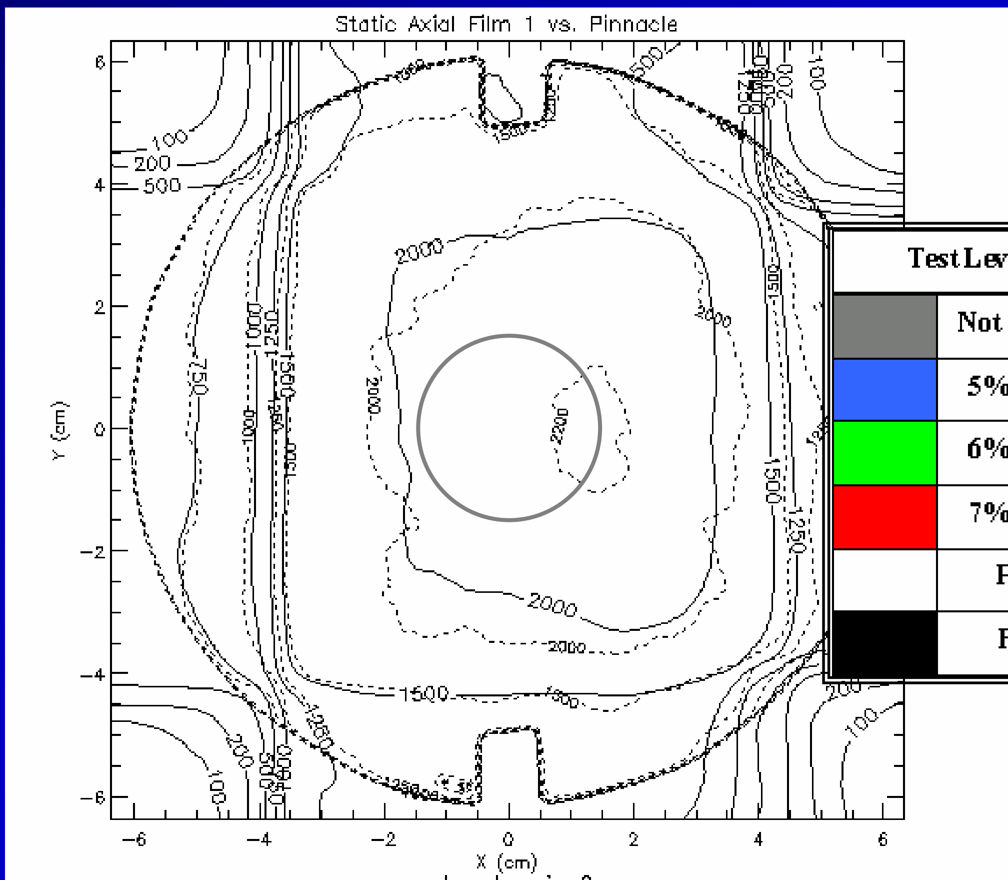
Average axial AP profile from normalized film and Pinnacle[3] calculated profile comparison for the static plan

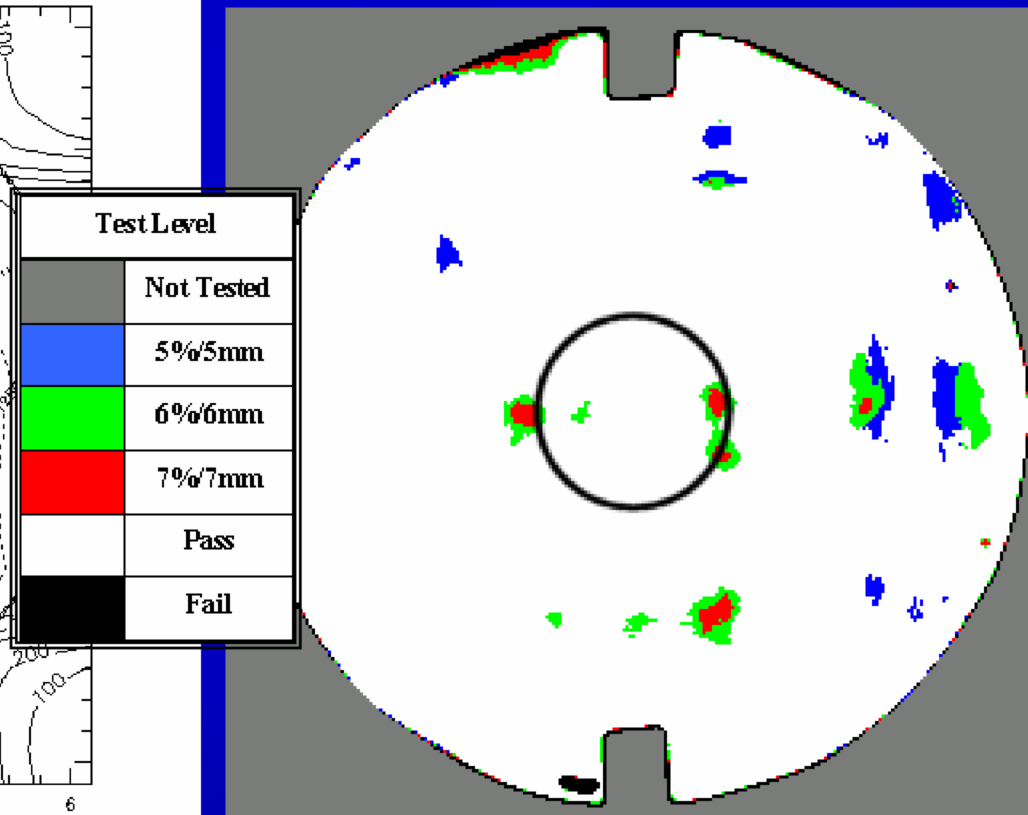


Results (Static Plan)

Isodose comparison of film (dashed) vs. calculated (solid)

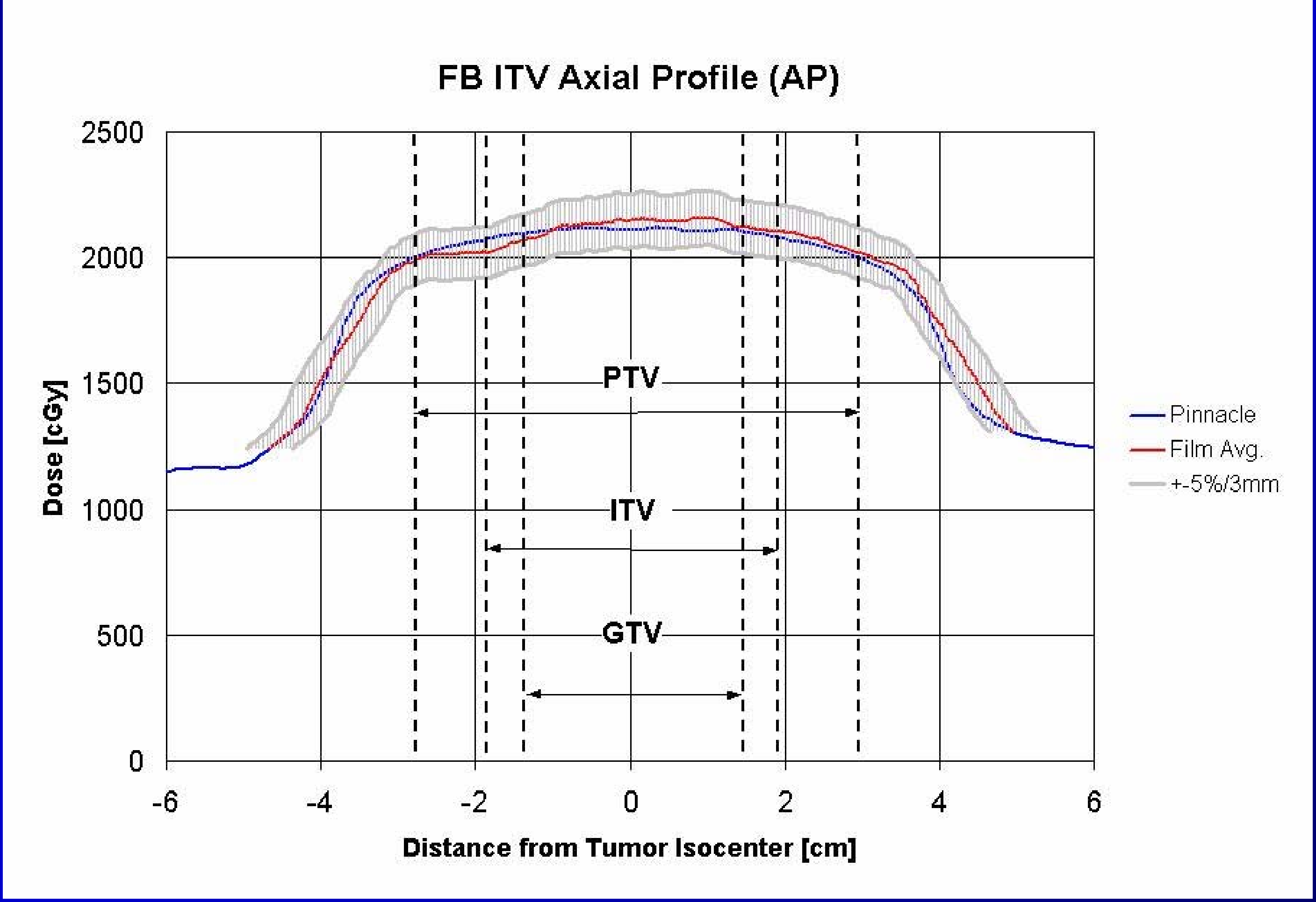
Binary agreement map results from 5%/3mm – 7%/7mm





Results (FB ITV Plan)

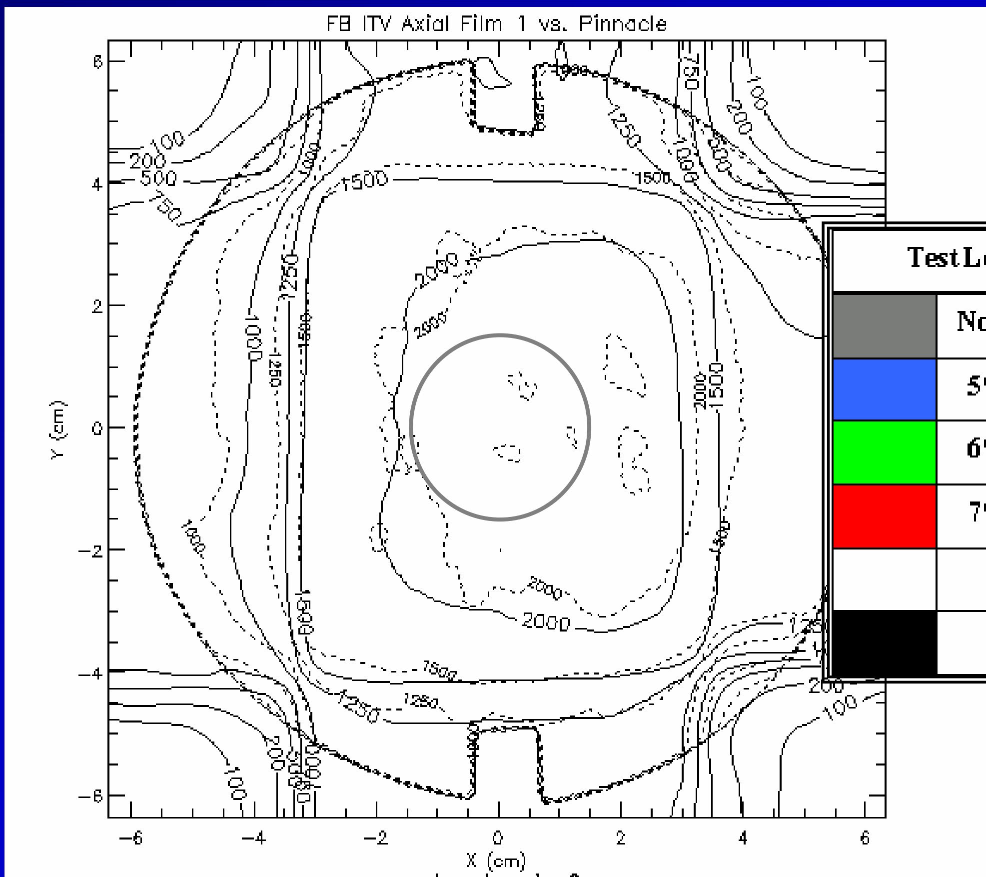
Average axial AP profile from normalized film and Pinnacle[3] calculated profile comparison for the free-breathing ITV plan

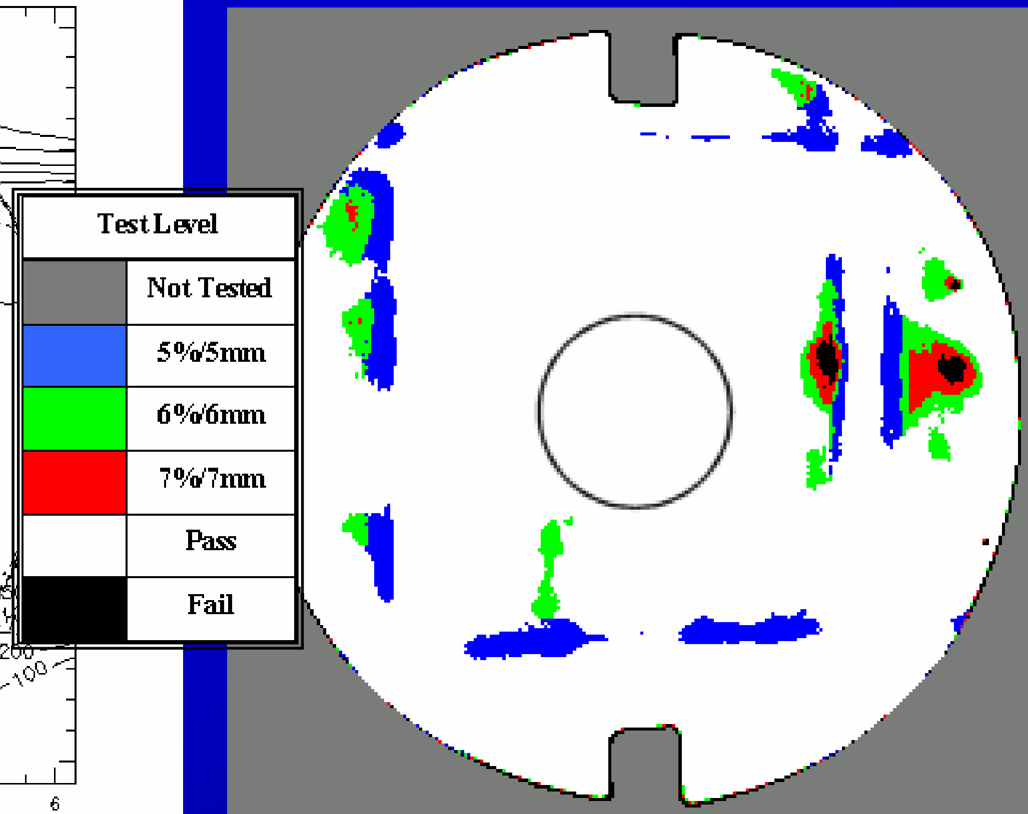


Results (FB ITV Plan)

Isodose comparison of film (dashed) vs. calculated (solid)

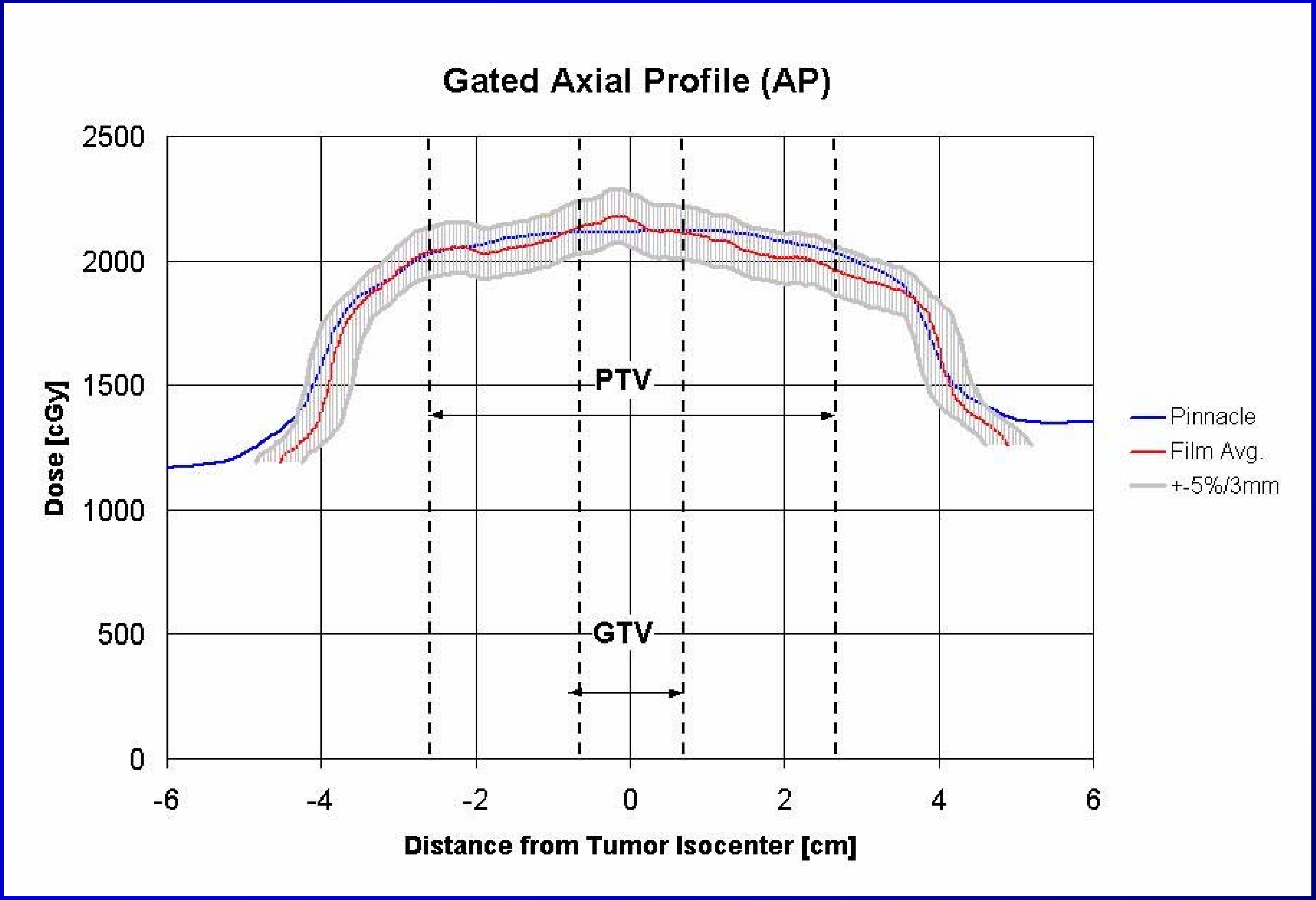
Binary agreement map results from 5%/3mm – 7%/7mm





Results (Gated Plan)

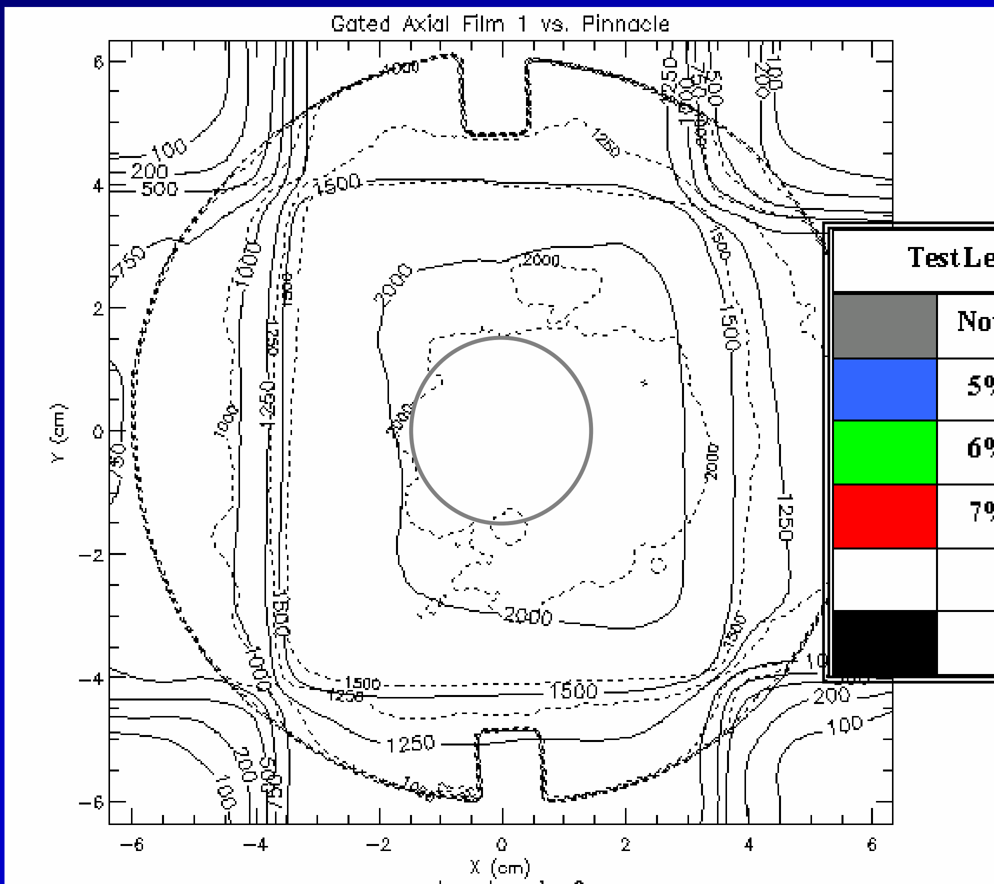
Average axial AP profile from normalized film and Pinnacle[3] calculated profile comparison for the gated plan

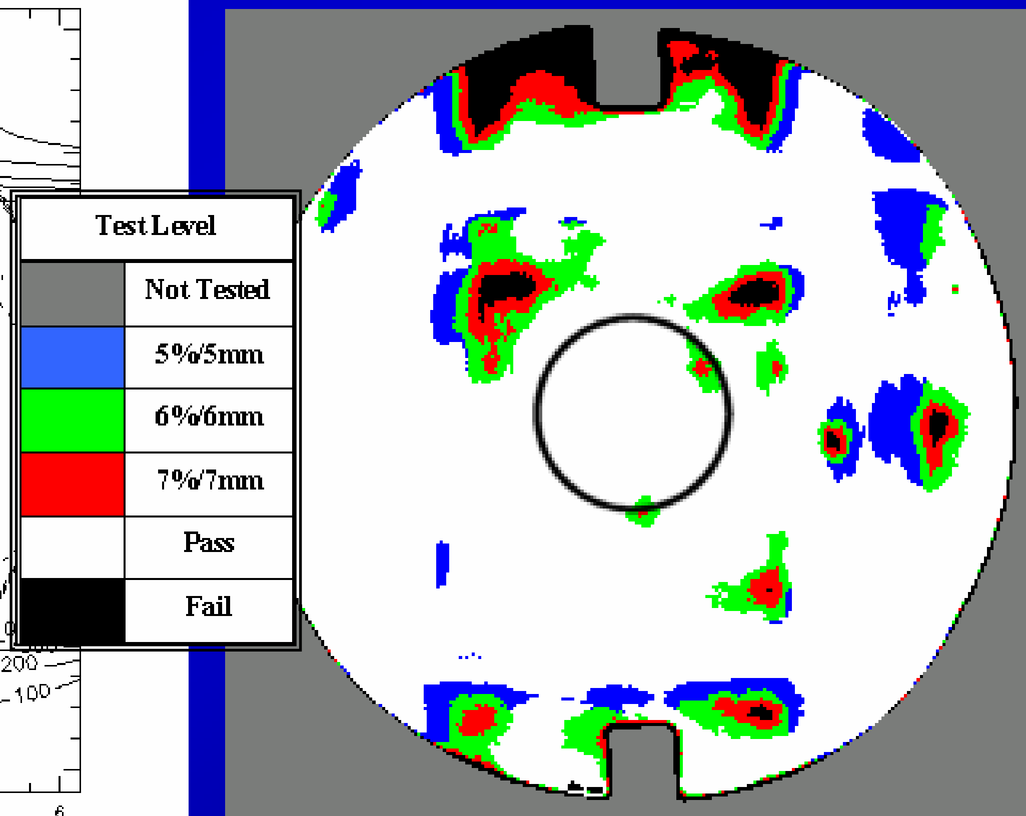


Results (Gated Plan)

Isodose comparison of film (dashed) vs. calculated (solid)

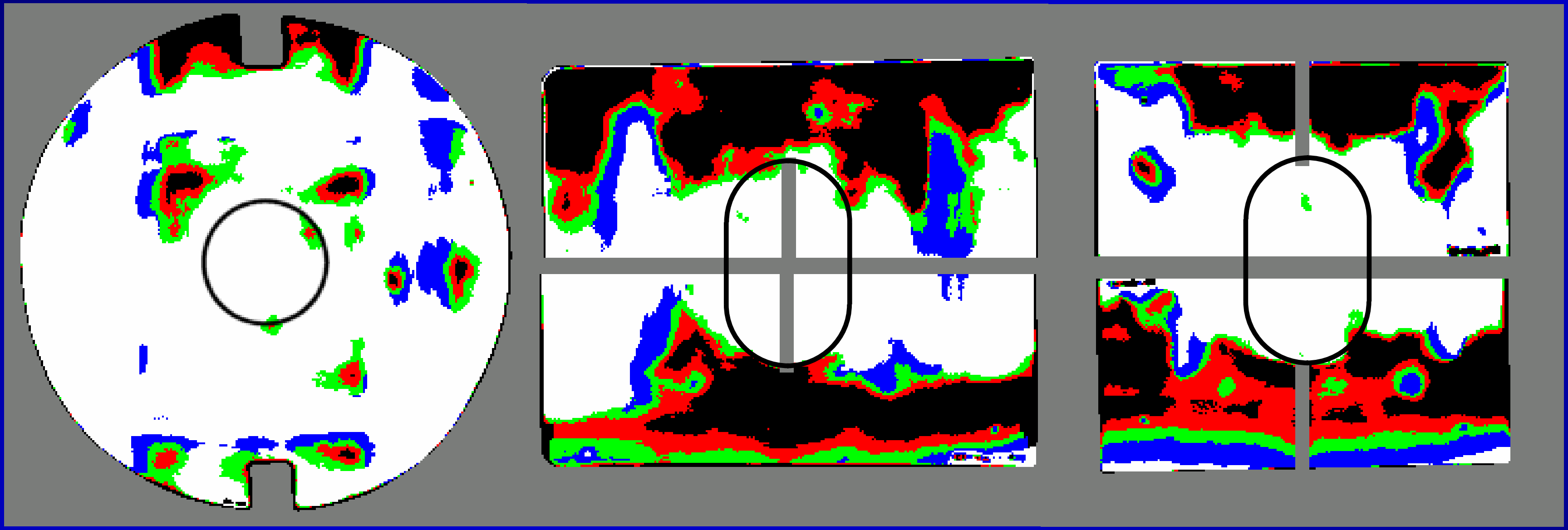
Binary agreement map results from 5%/3mm – 7%/7mm





Results (Gated Plan)

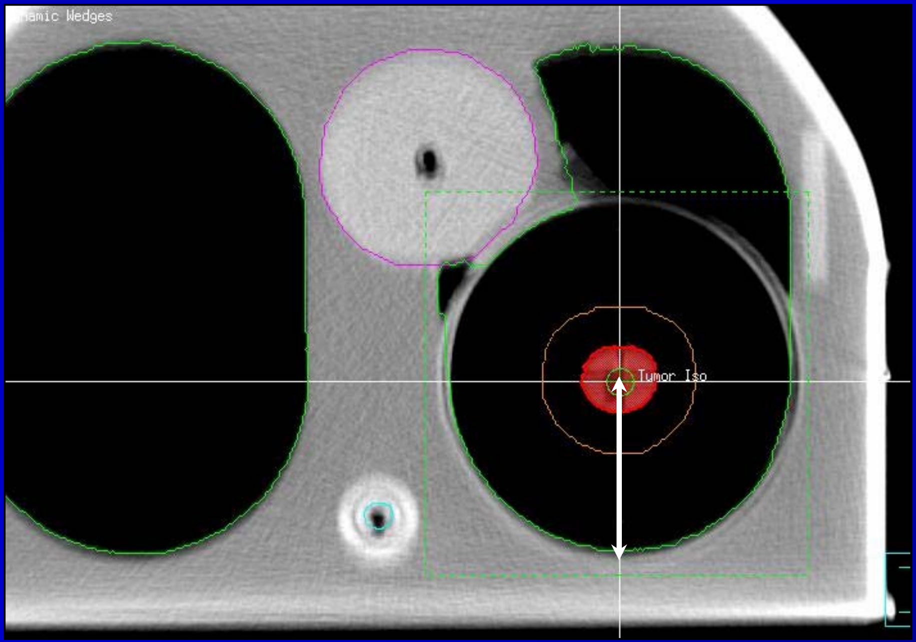
Results for 3 film planes

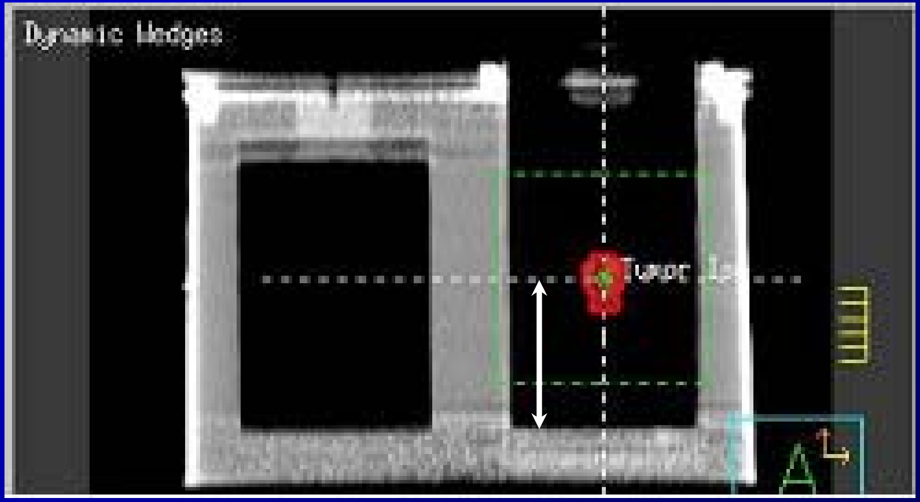


Axial Coronal Sagittal

Results (Gated Plan)

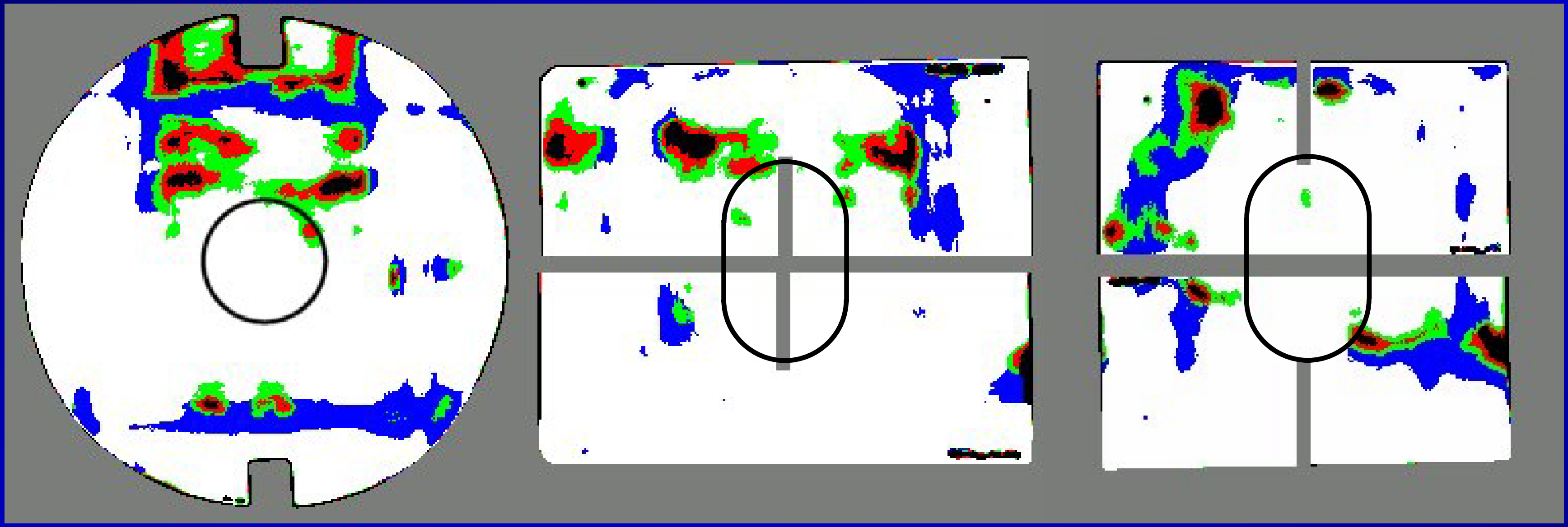
- Gated irradiation revealed tumor centroid displacement in the anterior and superior directions due to respiratory motion CT artifact.





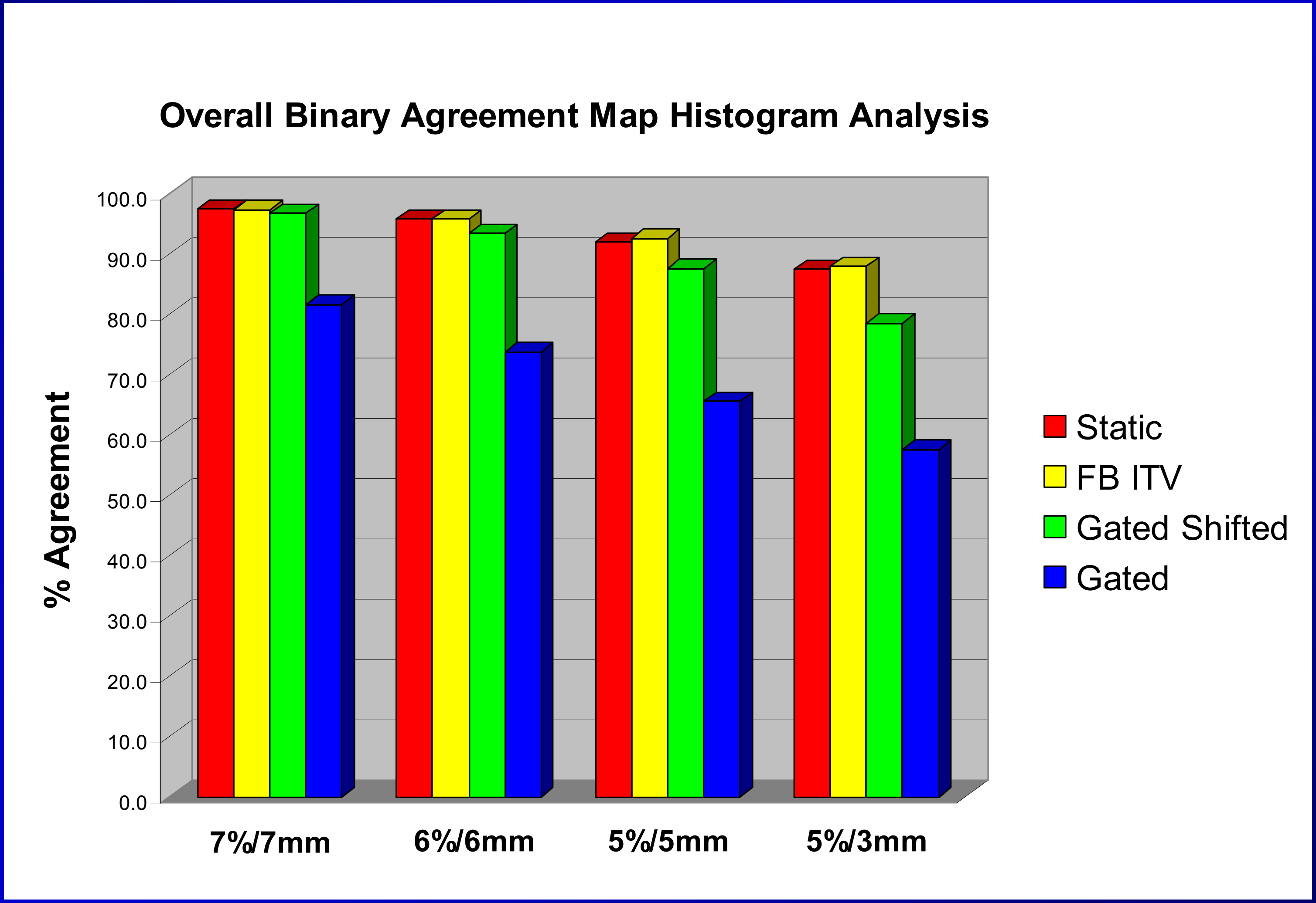
Results (Gated Plan)

Improved results for gated data with Pinnacle^3 data shifted.



Axial Coronal Sagittal

Results
(Binary Comparison Summary)



Conclusions

- The phantom QA system was simple to use and produced reliable operation throughout several trials of use.

- The phantom QA system works well in a typical clinical environment and produced good results for CT imaging reproducibility, treatment planning and treatment delivery for the static and FB ITV techniques.

- The phantom QA system indicates that the gated technique should be used with caution during the simulation and treatment planning stages to avoid a potentially serious error in radiation isocenter placement.

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