Risk of Secondary Fatal Malignancies from Hi-Art Tomotherapy

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Advantages of IMRT

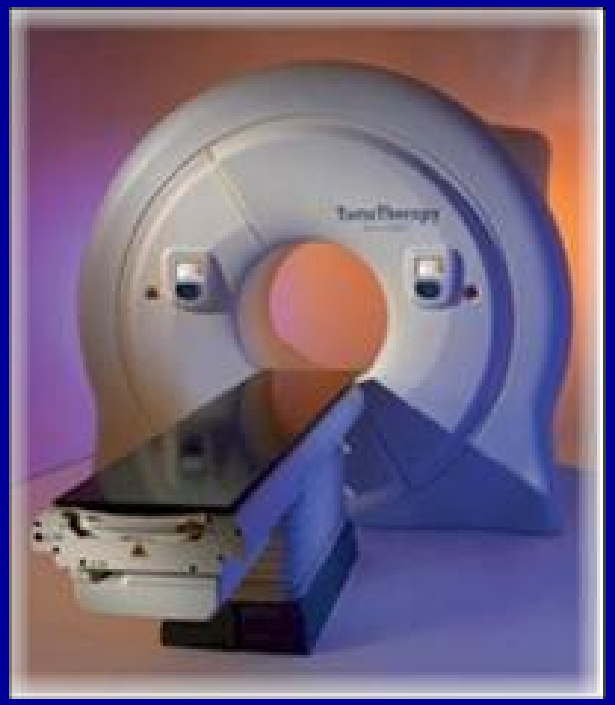
- Dose escalation to the target
- Conformal radiation dose to the target volume while sparing more normal surrounding tissue from higher doses

Disadvantages to Consider

- Kry et al.
  - IMRT requires more monitor units (beam on time)
  - Higher secondary doses to normal tissue
  - Harmful effects from irradiating normal tissue, include induction of secondary cancers

Hi-Art Tomotherapy

- IMRT via helical dose delivery
  - Very conformal target doses
  - Larger volume of low doses to normal tissues
- Treatment times can be longer than for conventional gantry based IMRT
  - Prostate treatment nearly equal times (~12 min)
  - Pediatric CSI much longer
    - ~10 min/fx for 3D versus 20 min/fx for tomotherapy



Risk of Second Cancers

- Eric J. Hall. Intensity-Modulated Radiation Therapy, Protons, and The Risk of Second Cancers. 2006
  - A linear relation exists between cancer and dose from about 0.1 Sv up to about 2.5 Sv (BEIR VII report, 2006)
  - Incidence of second cancers higher in children
    - Adults ~5%/Sv
    - Children ~15%/Sv
  - “Radiation scattered from the treatment volume is more important in the small body of a child.”

Purpose

- Comparison of secondary doses and associated cancer risk factors from gantry based delivery to that from Tomotherapy

Procedure

- Adult Prostate Treatment
  - Same prescription for conventional IMRT and Tomotherapy treatments plans
  - TLD placement in anthropomorphic phantom
  - Organ doses from TLD
  - Risk Estimates (Linear non threshold, BEIR VII)

Procedure

- Pediatric Cranio-Spinal Irradiation (CSI)
  - Same prescription for 3D and Tomotherapy treatment plans
  - TLD and EBT film placement in pediatric anthropomorphic phantom
  - Organ doses from TLD
  - EBT film validation of TPS calculations
  - Risk Estimates (Linear non threshold, BEIR VII)
    - TLD
    - DVH – whole organ risk estimates

Adult Prostate Treatment: IMRT vs. Tomo TLD Results

Organ site	Lifetime Risk of Cancer Mortality, %/Sv	Avg Dose from IMRT trials, cGy	Gantry risk %	Avg Dose from Tomo trials, cGy	Tomo risk %
Thyroid	**0.005	6.28	**0.00	2.38	**0.00
Esophagus ctr		7.08		4.20	
Esophagus edge		14.71		10.21	
Lt. Lung center	0.89	7.66	0.07	5.08	0.05
Lt. Lung edge	0.89	12.95	0.12	9.37	0.08
Liver center	0.11	18.75	0.02	12.22	0.01
Liver edge	0.11	34.69	0.04	18.80	0.02
Stomach center	0.11	29.00	0.03	15.61	0.02
Stomach edge	0.11	37.94	0.04	20.17	0.02
Colon	0.47	37.20	0.18	27.56	0.13

**Lifetime attributable risk of cancer incidence

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Pediatric CSI: 3D vs. Tomo TLD Results

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Thyroid	**2.5	2797.4	**69.2	362.4	**9.0
Lt. Breast Bud	2.1	151.9	3.2	437.5	9.4
Heart center		2957.4		864.9	
Heart edge		2344.9		428.0	
Lt. Lung ctr	4.0	226.4	9.0	907.3	36.2
Lt. Lung edge	4.0	242.2	9.7	446.1	17.8
Liver center	0.3	2583.4	7.4	1107.1	3.2
Liver edge	0.3	216.5	0.6	544.6	1.6
Lt. Kidney		221.1		747.8	
Bladder	0.4	194.8	0.9	76.9	0.3
Pelvic bone marrow	0.6	85.7	0.5	528.5	3.3
Lt. Ovary	0.5	322.2	1.5	135.3	0.6

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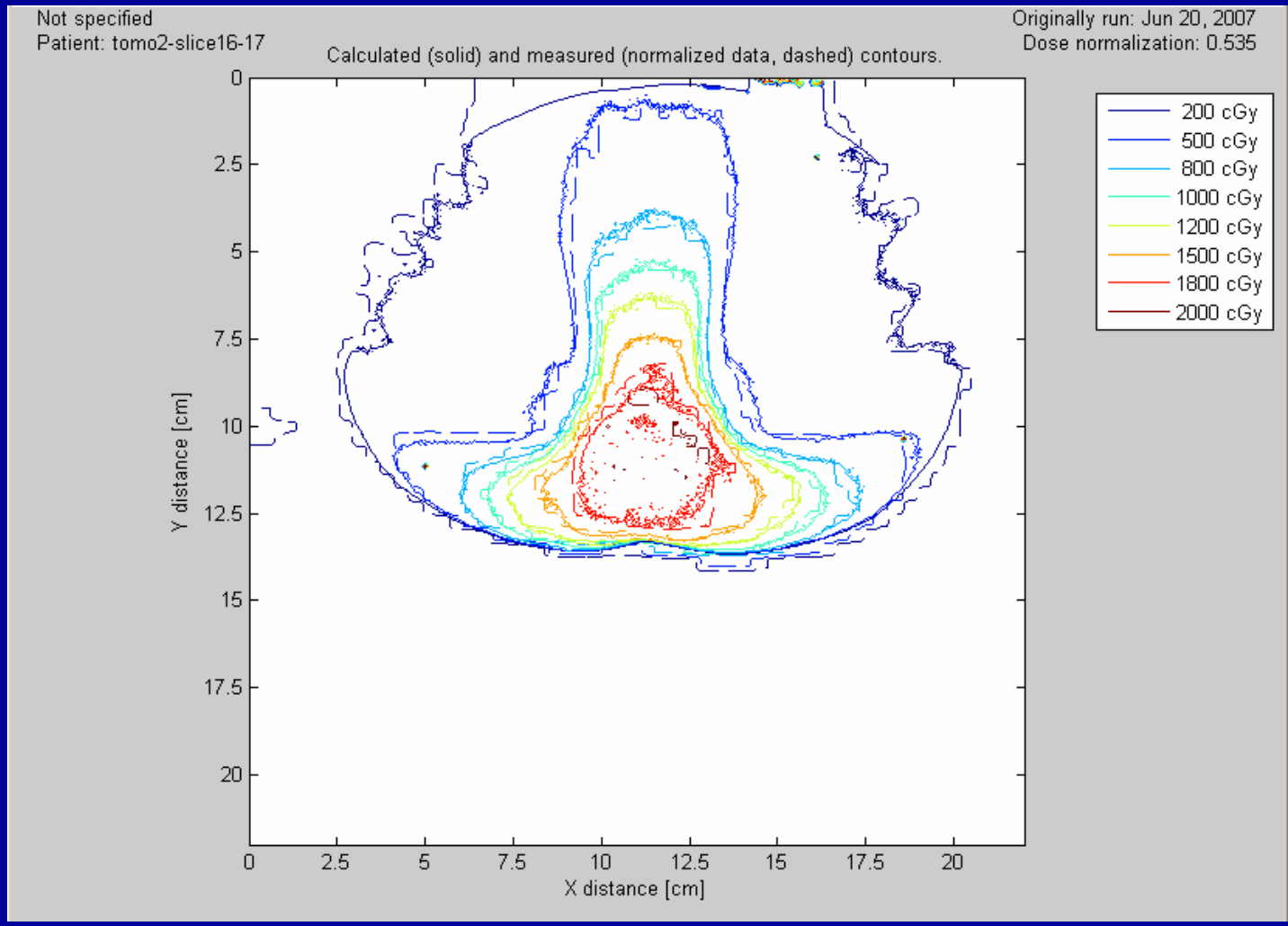
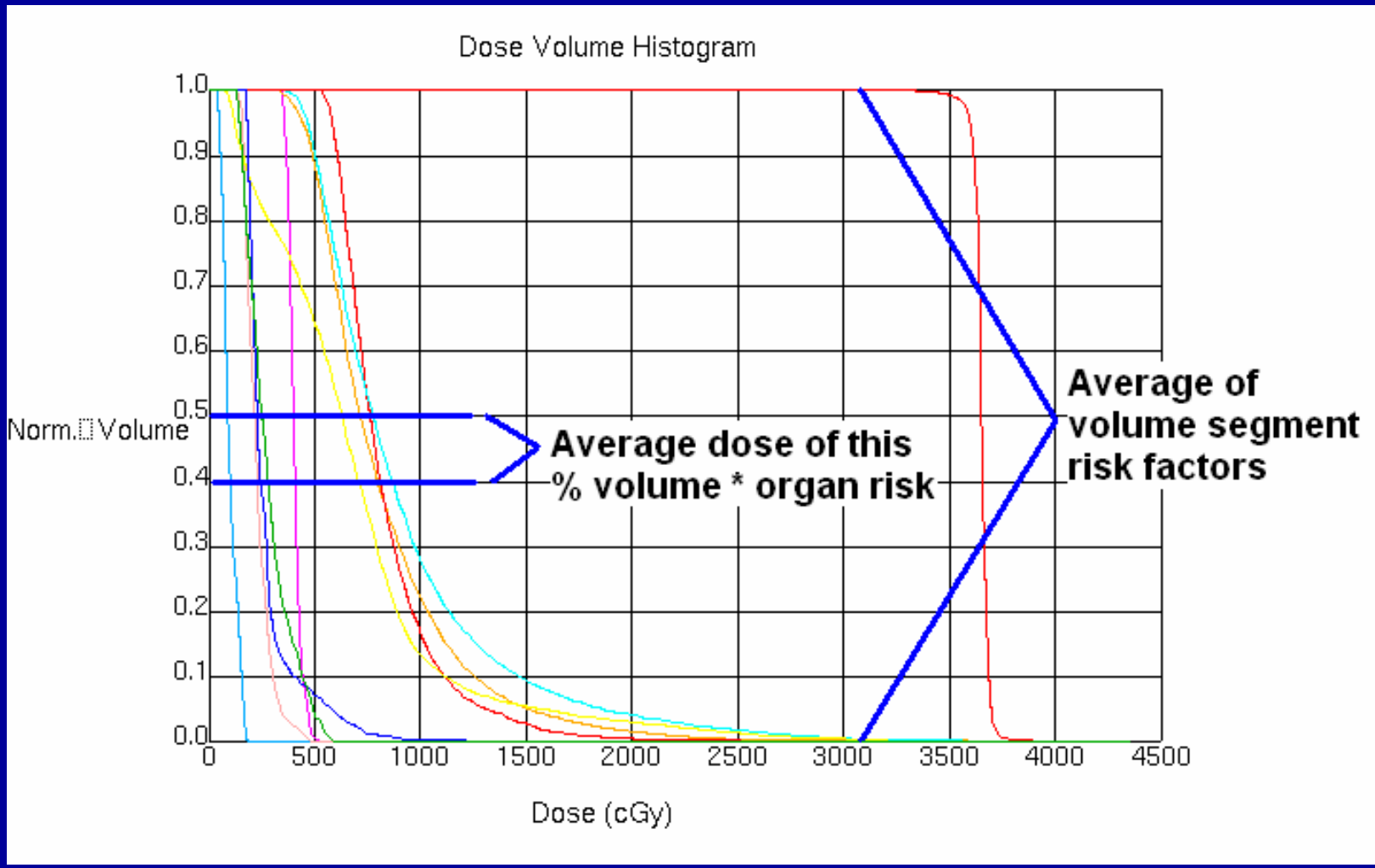
**Lifetime attributable risk of cancer incidence

Pediatric Phantom: Film Results



Pediatric CSI:
DVH Analysis Procedure

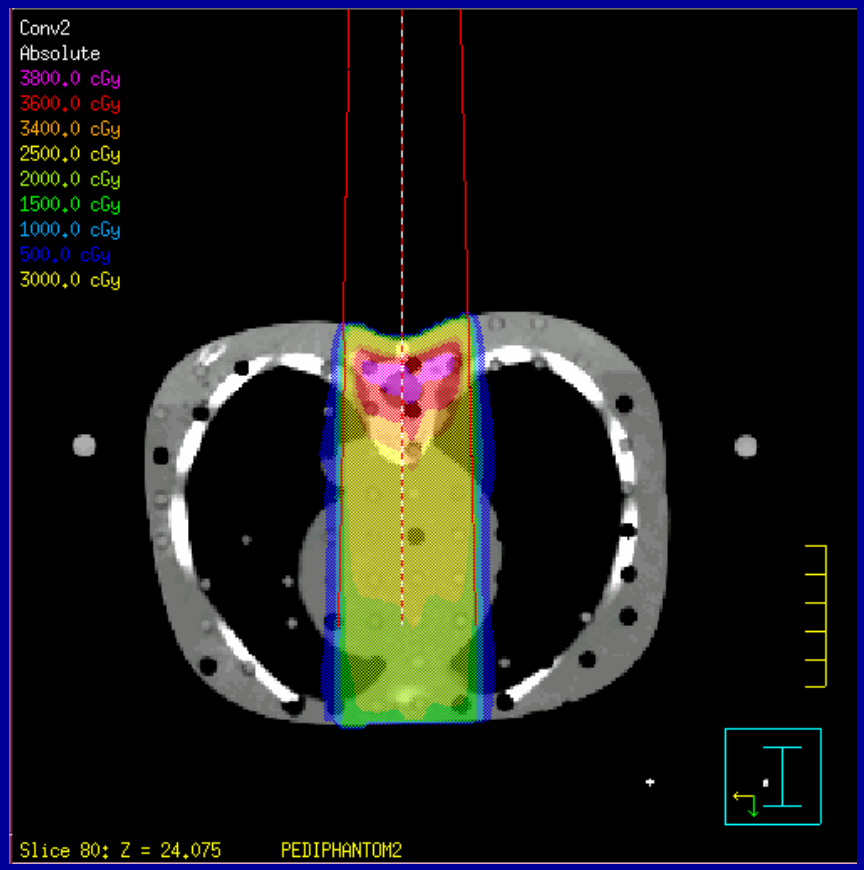


Pediatric CSI: DVH Analysis

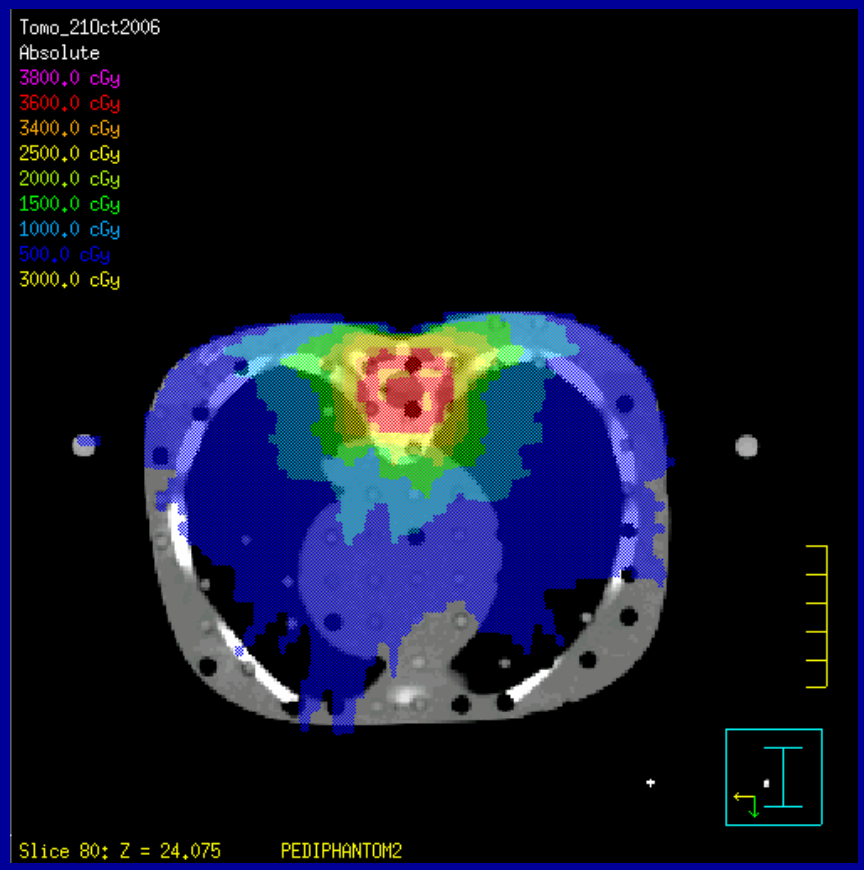
Organ	3D Treatment: Average of segment risk estimates, %	Tomo Treatment: Average of segment risk estimates, %
Thyroid	**69.2	**7.1
Breast tissue	2.9	8.3
Lt. Lung	19.2	35.4
Liver	3.5	2.4
Bladder	0.9	0.5
Pelvic bone marrow	4.5	4.4
Ovaries	1.1	1.2

**Lifetime attributable risk of cancer incidence

3D vs. Tomotherapy: Lung Dose Distribution



3D Dose Distribution



Tomo Dose Distribution

Conclusions

- Adult prostate treatments
  - Lower risk estimates from Tomotherapy
- Pediatric cranio-spinal treatments
  - Mixed results
- Other proposed risk models have not been validated, so only the LNT model was used.

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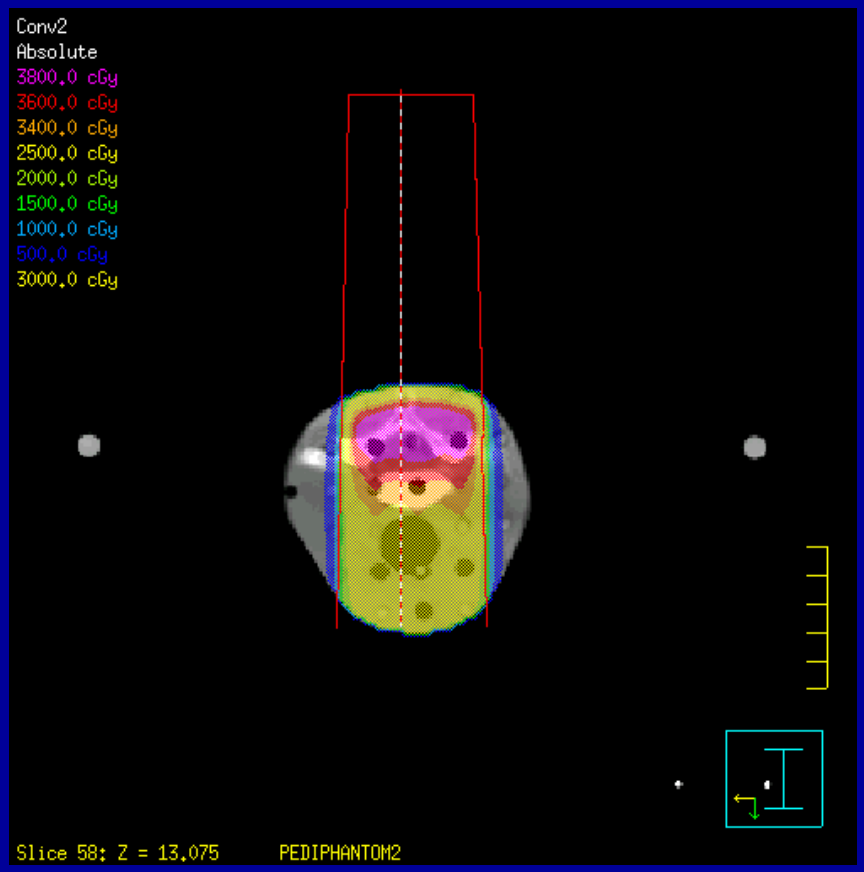
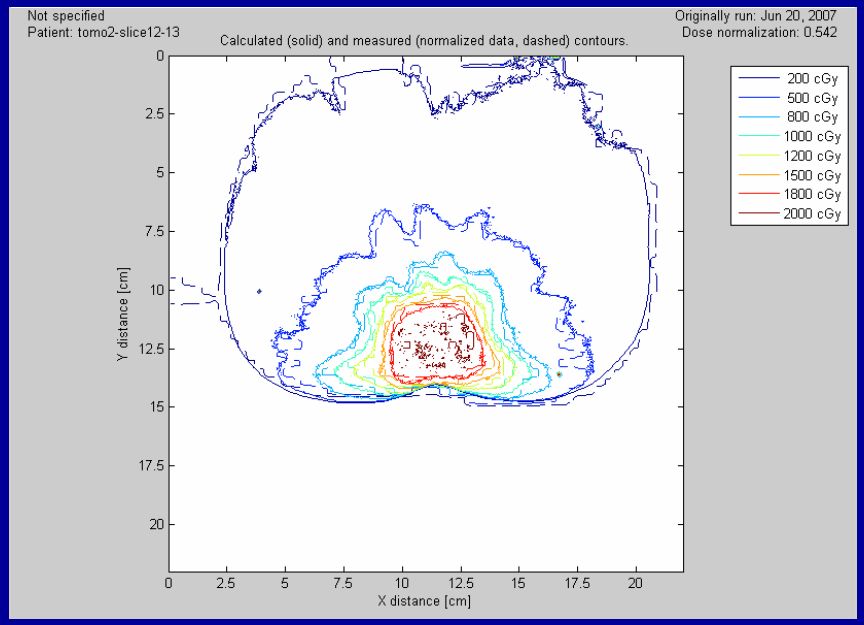
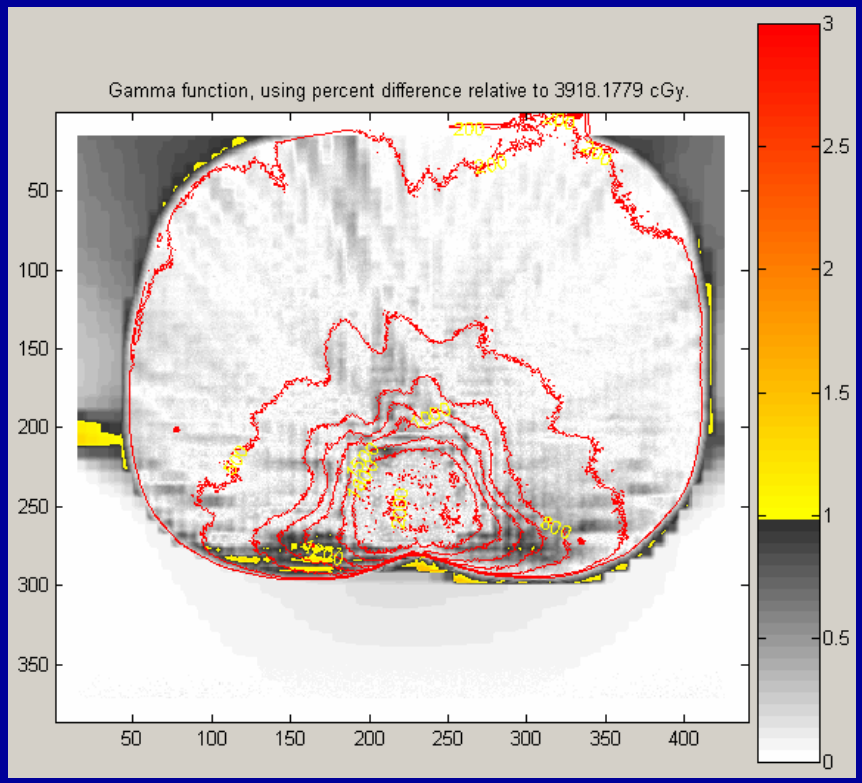
- Followill et al. Estimates of the Whole-Body Dose Equivalent Produced by Beam Intensity-Modulated Conformal Therapy. Int. J. Rad. Onc. Biol. Phys. 38: 667-672, 1997.
- Eric J. Hall. Intensity-Modulated Radiation Therapy, Protons, and The Risk of Second Cancers. Int. J. Rad. Onc. Biol. Phys., Vol. 65, No. 1, pp. 1-7, 2006.

3D vs. Tomotherapy: Thyroid Dose Distribution



Pediatric CSI: Film vs. Tomo Plan Comparison





99.3% of pixels pass gamma for 5% relative dose/3 mm criteria

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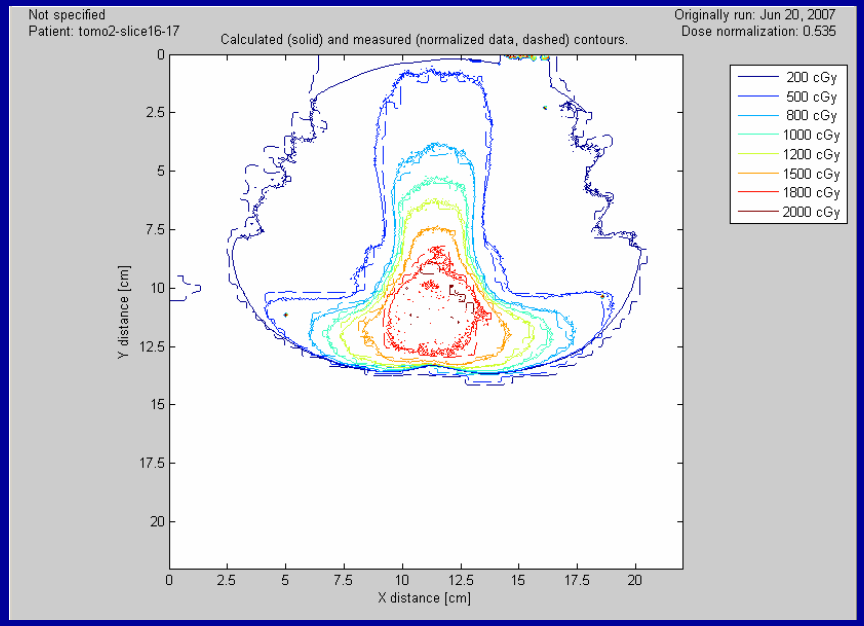

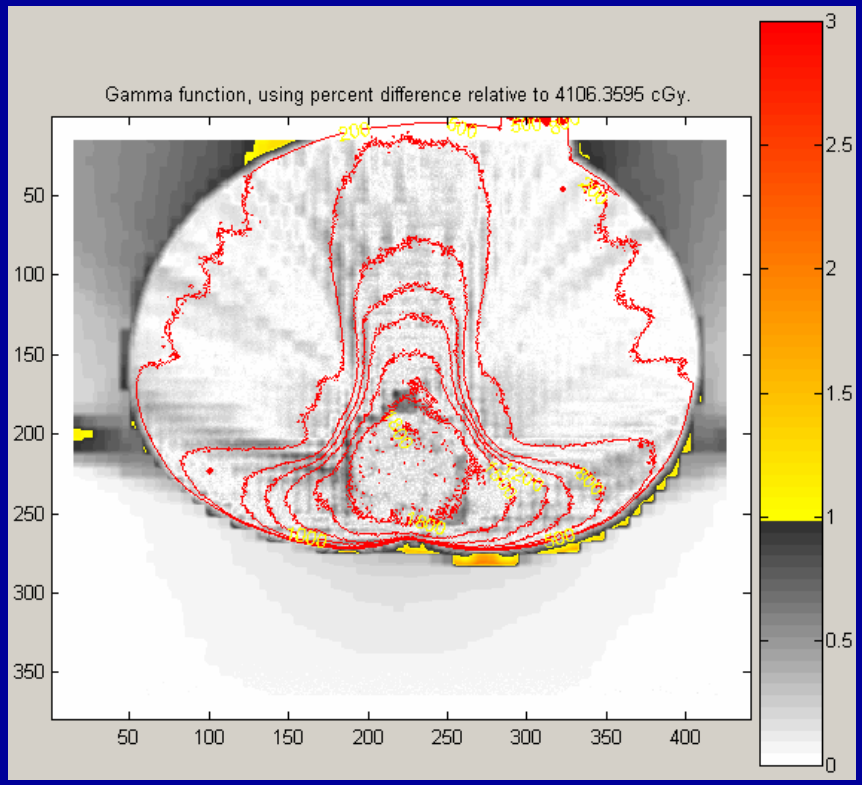

99.4% of pixels pass gamma for 5% relative dose/3 mm criteria