Princess Margaret Hospital
University Health Network

Integrating Technology for Radiotherapy in Prostate Cancer

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Radiation Medicine Program

Princess Margaret Hospital

Prostate Cancer - Canadian Consensus

Gleason score

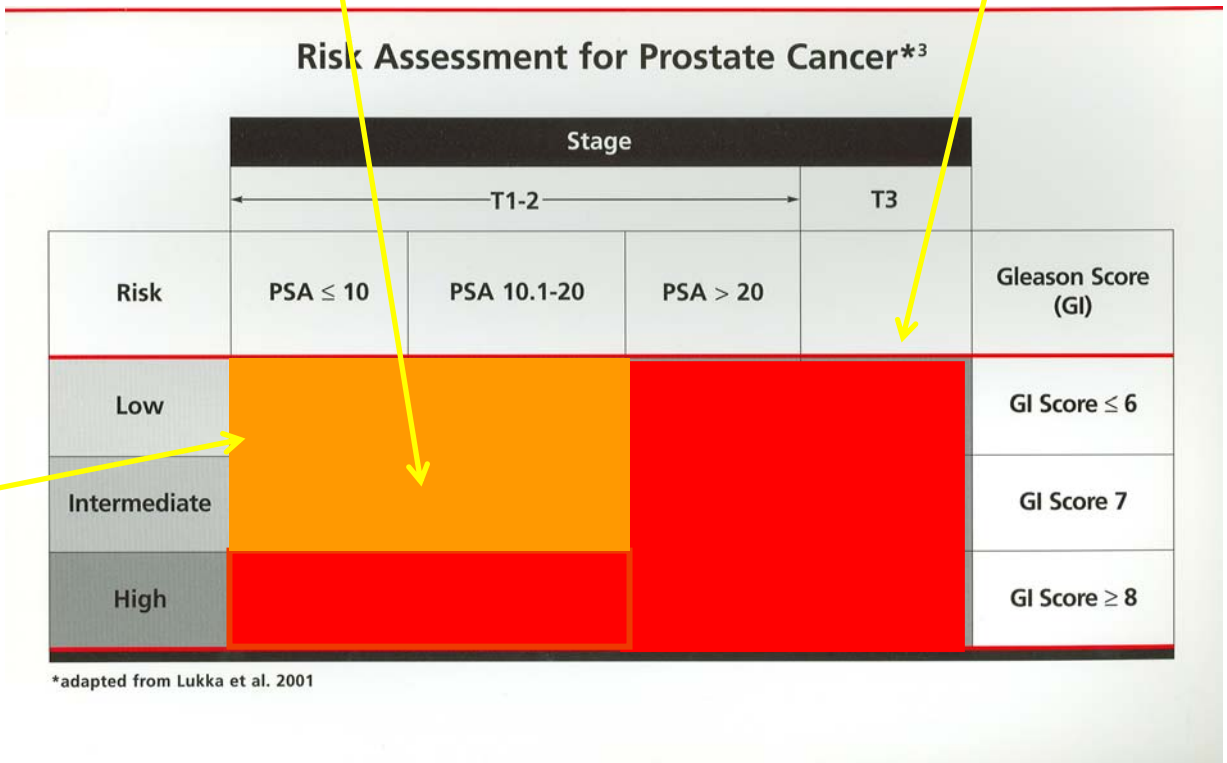
PSA

T-stage

Intermediate risk

High risk

Low risk



Radiotherapy Treatment Indications

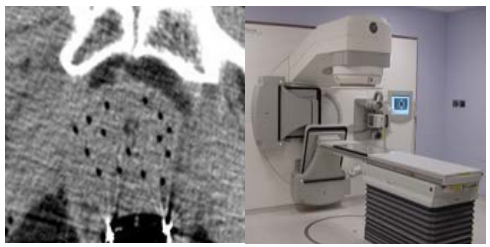
- Brachytherapy

Low risk

- External beam RT

Intermediate risk

- Combined B/EBRT



High risk

Postoperative

Results - Low risk

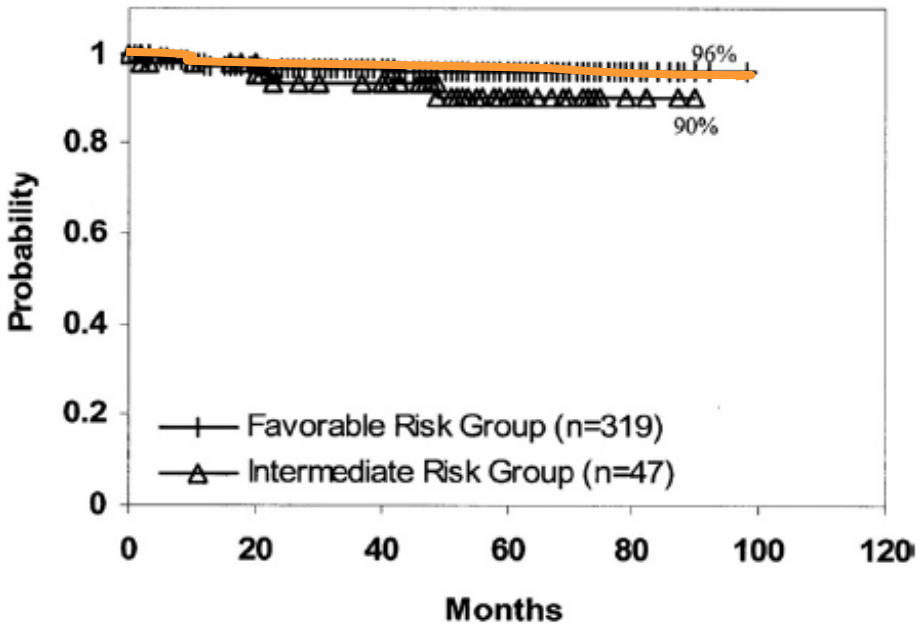


Fig. 1. ASTRO definition PSA relapse-free survival by NCCN recurrence risk group. Using the ASTRO definition for biochemical relapse, the 5-year actuarial PSA relapse-free survival outcomes for low and intermediate risk group patients were 96% and 90% ($p = 0.16$), respectively. ASTRO = American Society for Therapeutic Radiology and Oncology; NCCN = National Comprehensive Cancer Network; PSA = prostate specific antigen.

Zelefsky et al, 2007

Results - Intermediate risk

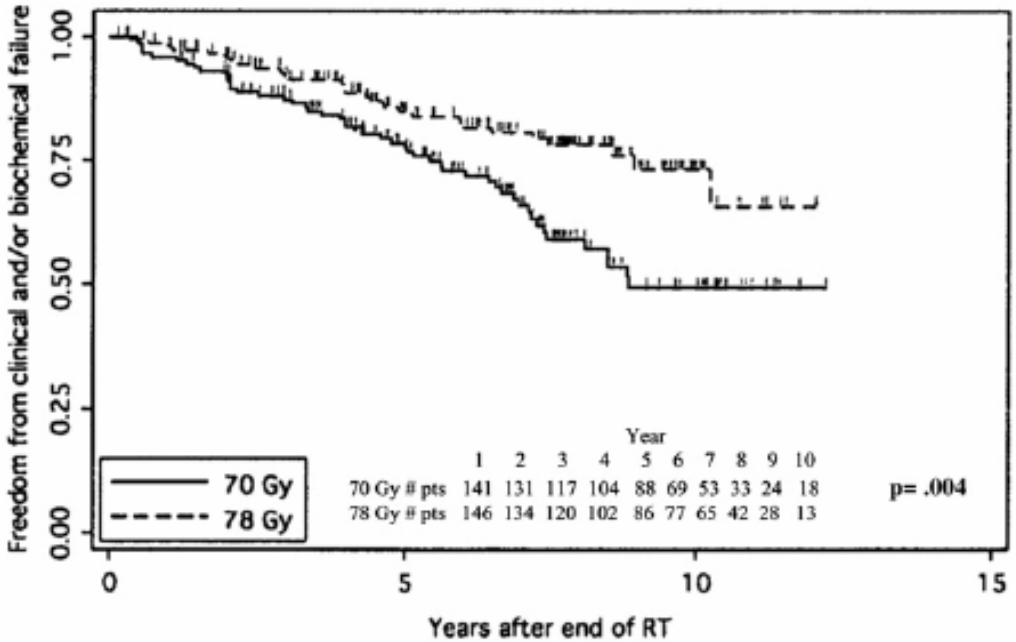
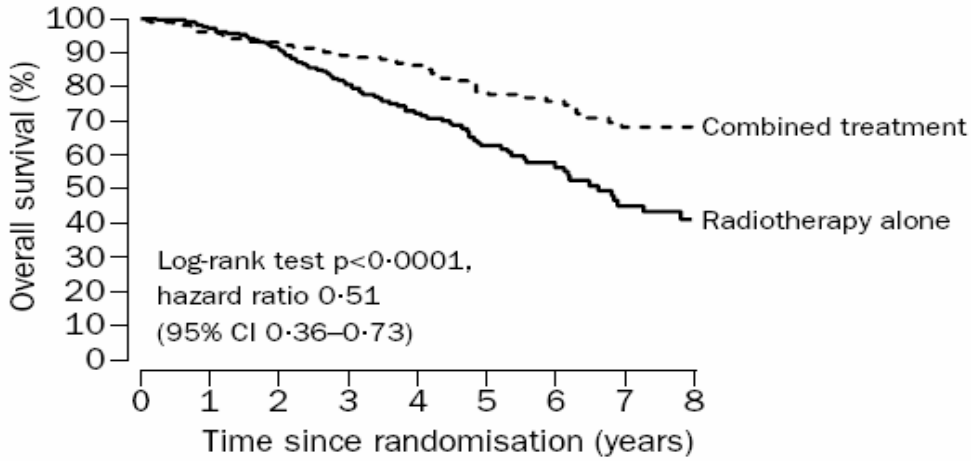


Fig. 1. Freedom from failure for all patients treated to 78 Gy versus 70 Gy.

Kuban et al, 2008

Results - High risk



O	N	Number of patients at risk							
81	208	199	177	146	106	70	46	30	16
50	207	197	183	166	142	93	71	43	24

Figure 2: **Kaplan-Meier estimates of overall survival by treatment group**

O=number of deaths: N=number of patients.

Bolla et al, 2002

Dose

- Large trials confirm that higher dose improve cancer control – become standard of care
  - Independent of type of radiation used
- Now - limit collateral injury to rectum, bladder, erectile structures
  - Reduce the volume of normal tissue exposed to high-dose

Approach

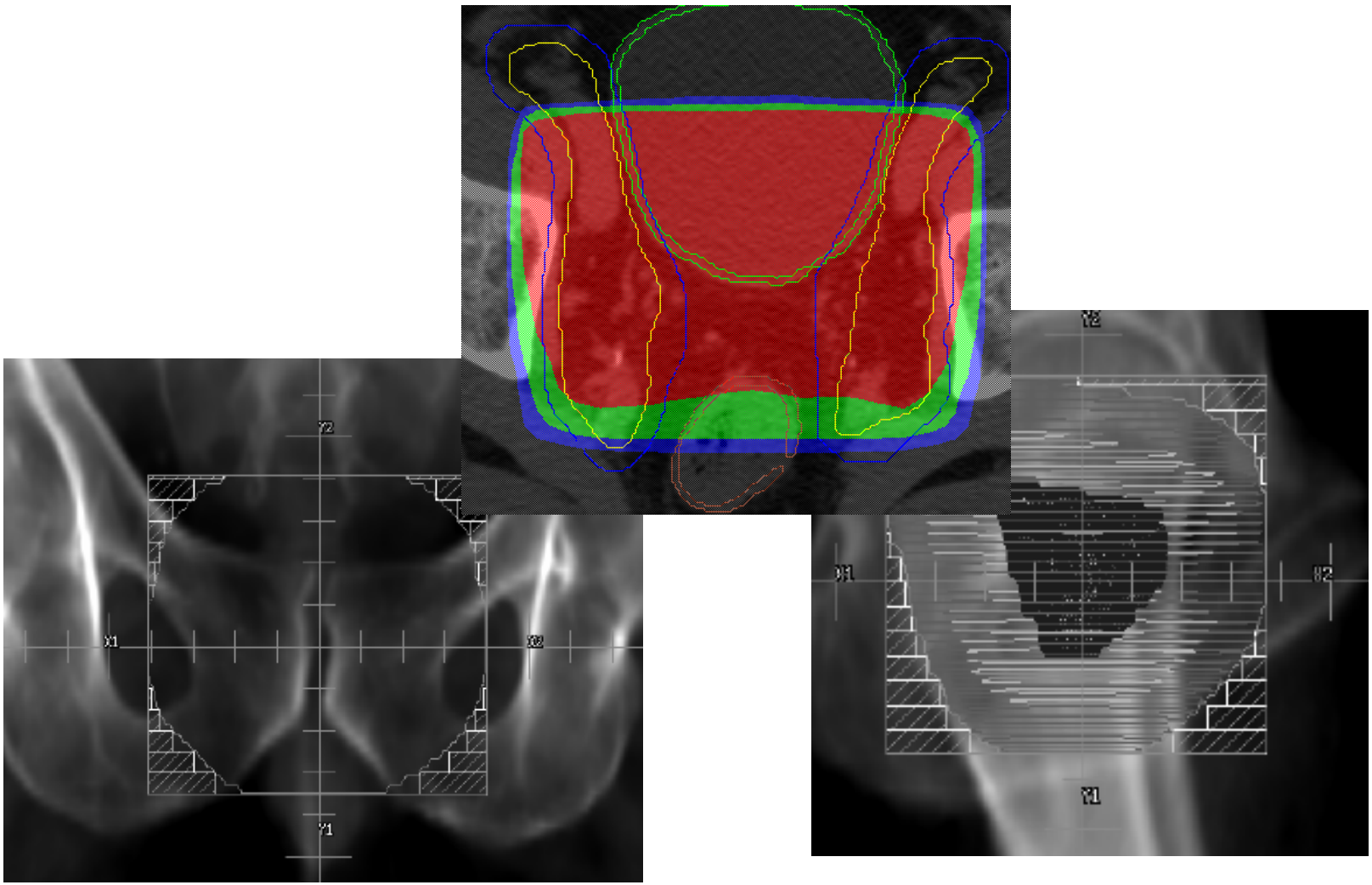
- Improve precision and accuracy
  - IMRT *(Intensity Modulated Radiotherapy)*
  - IGRT *(Image-Guided Radiotherapy)*

- Target cancer instead of organs
  - Imaging

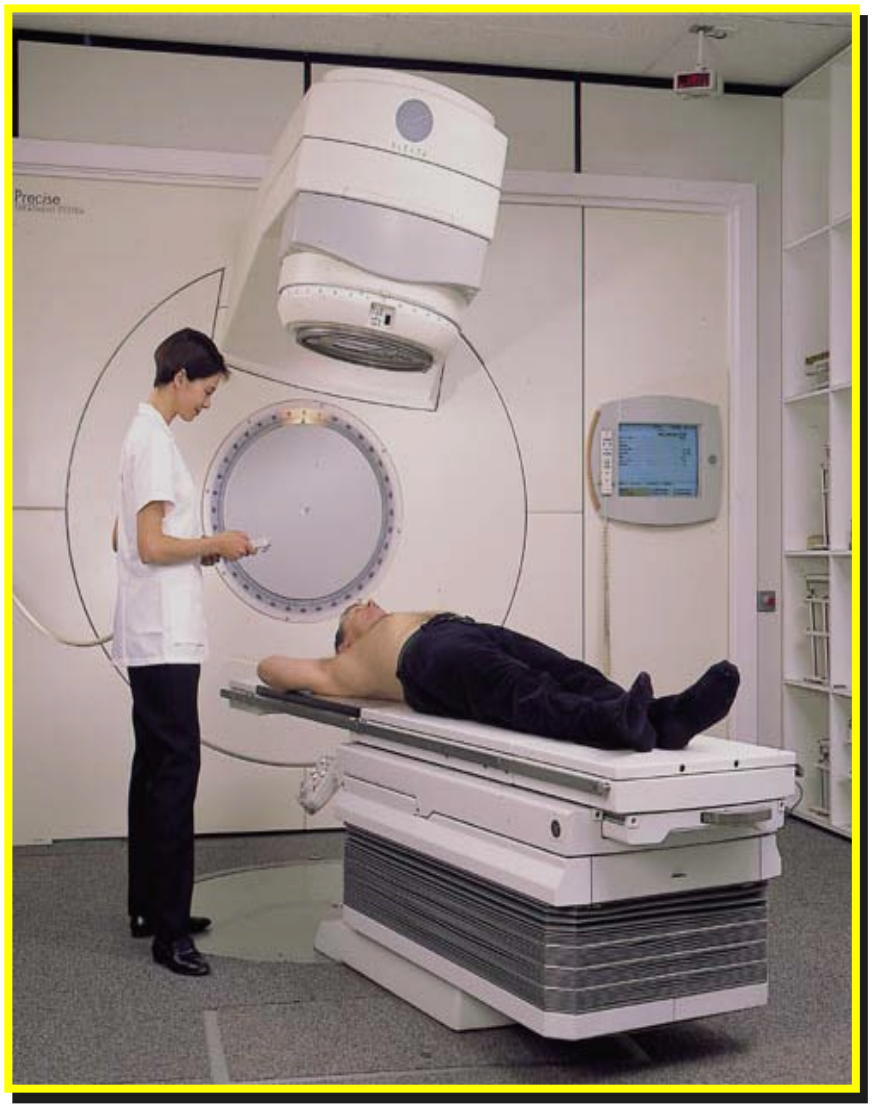
EBRT – Past

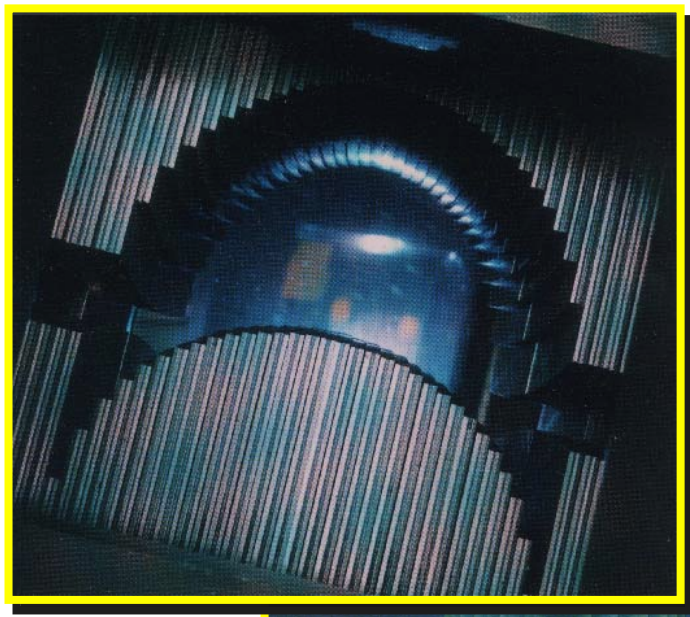
Cobalt ‘bomb’ – Johns et al

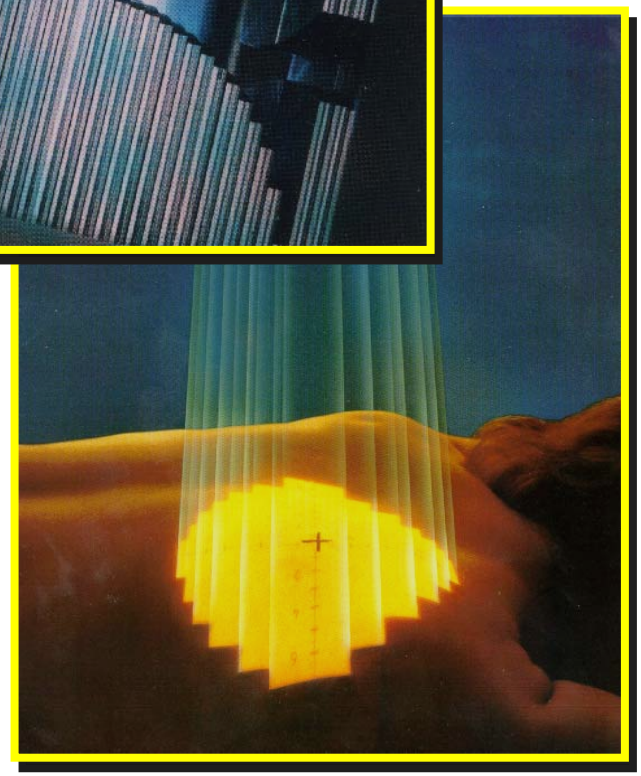
EBRT – Past



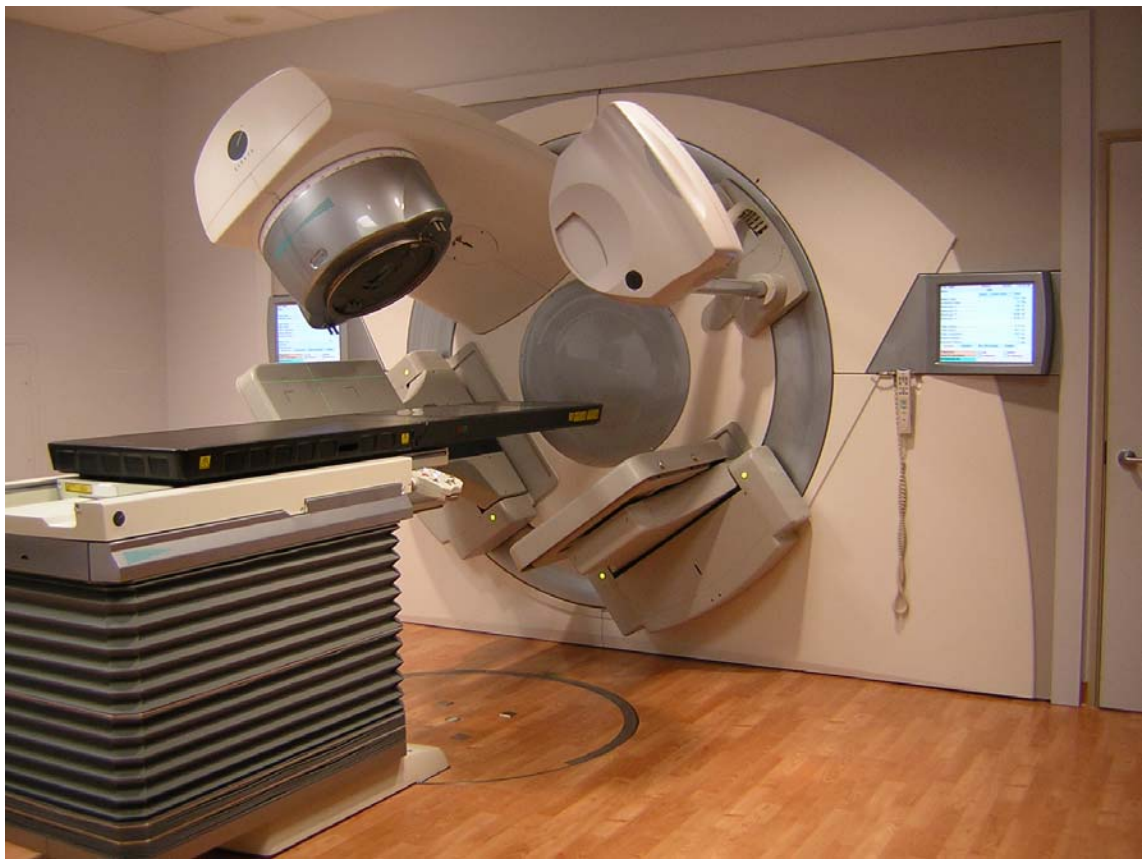
Linear Accelerator

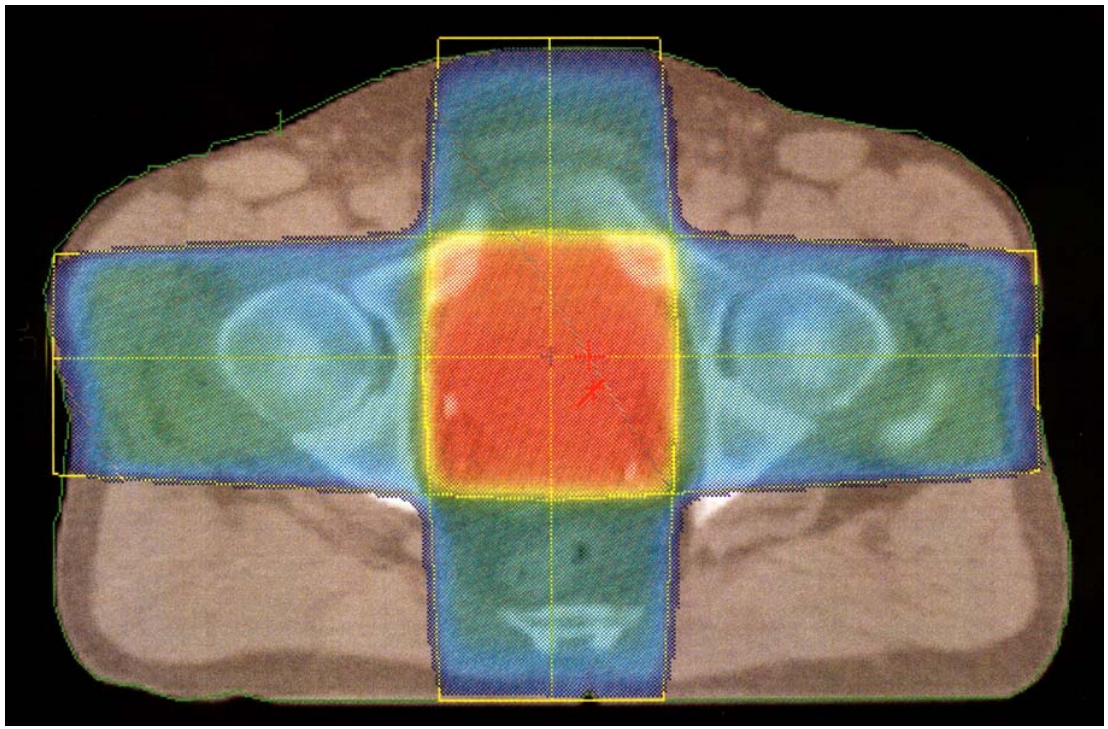


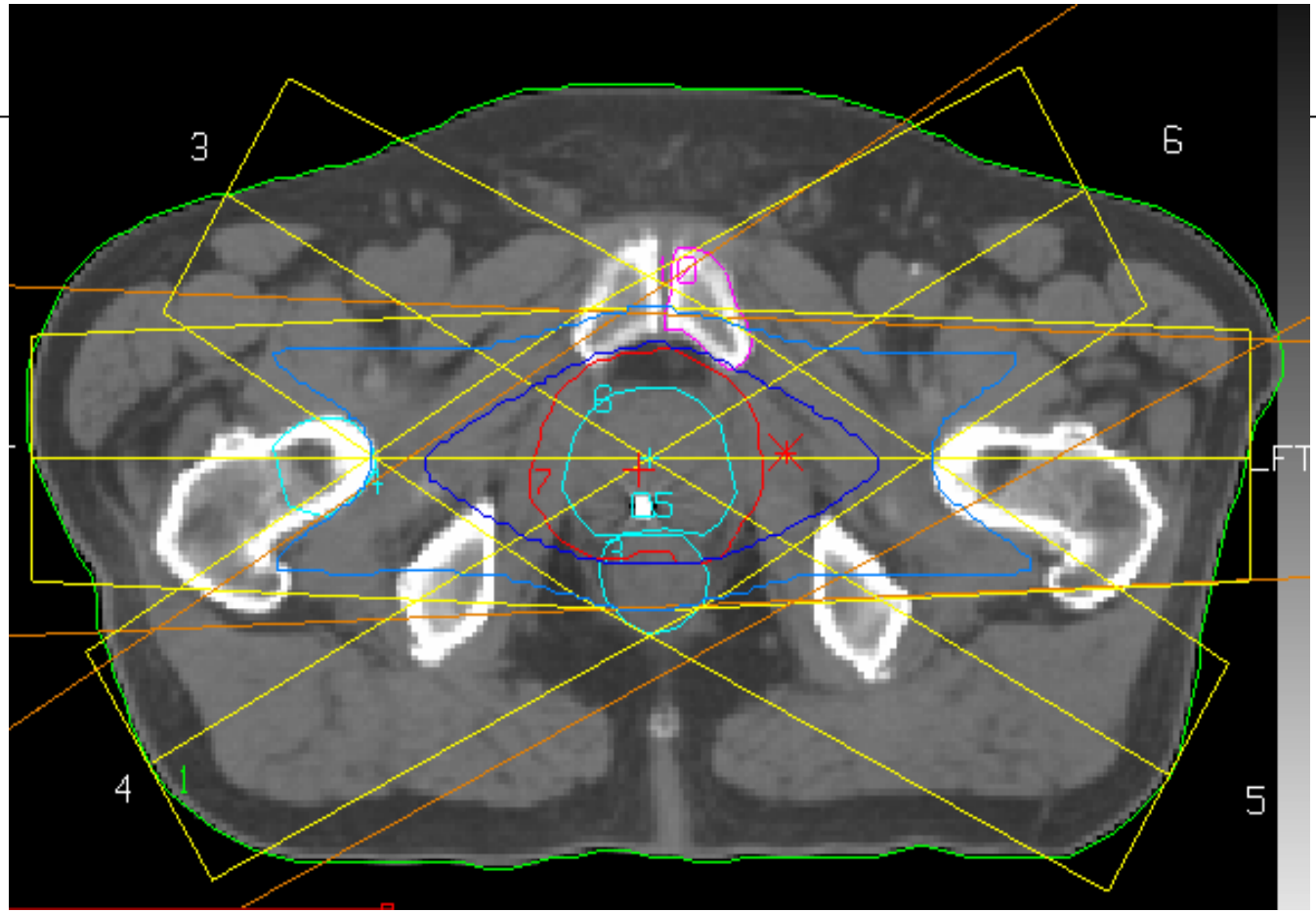


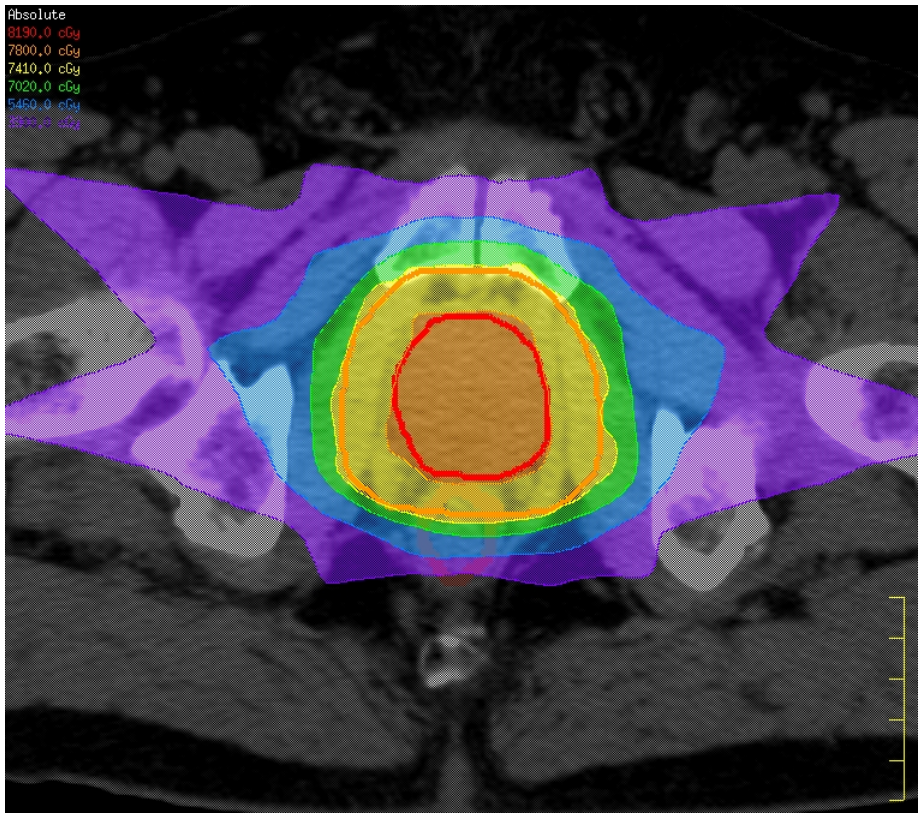


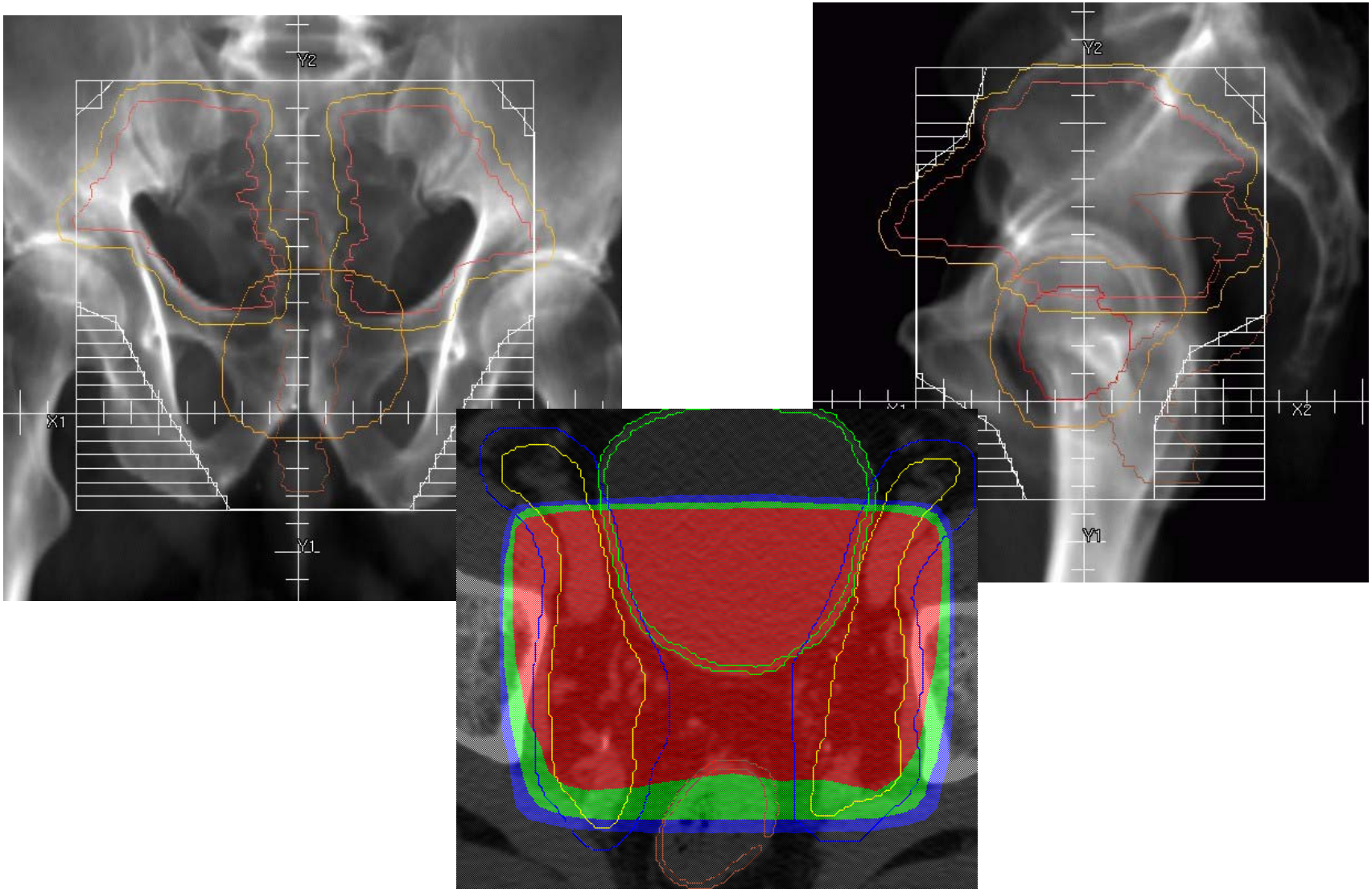
EBRT – Linear Accelerator



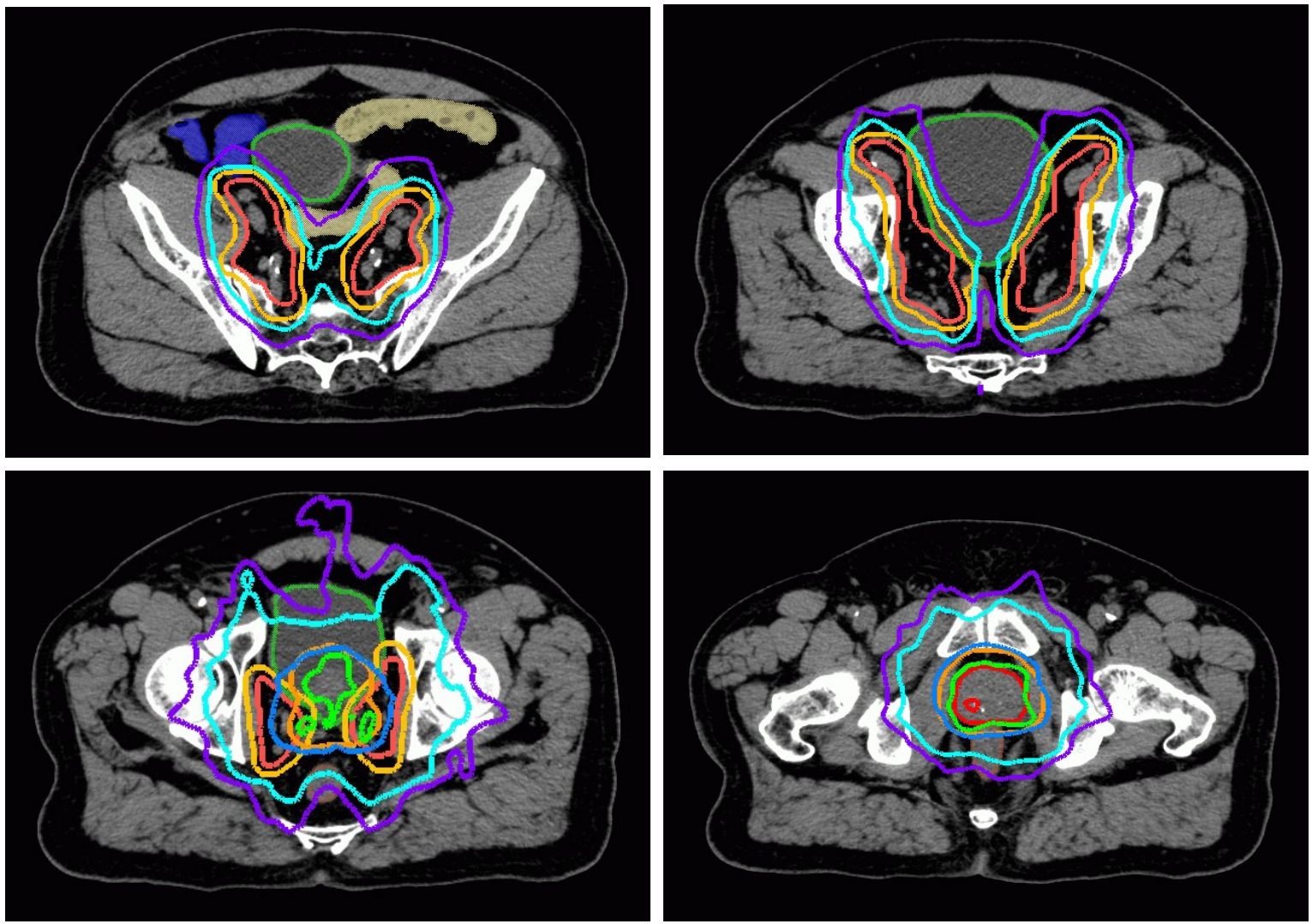



3
6
4
1
5
LFT


Absolute
8190.0 cGy
7800.0 cGy
7410.0 cGy
7020.0 cGy
5460.0 cGy

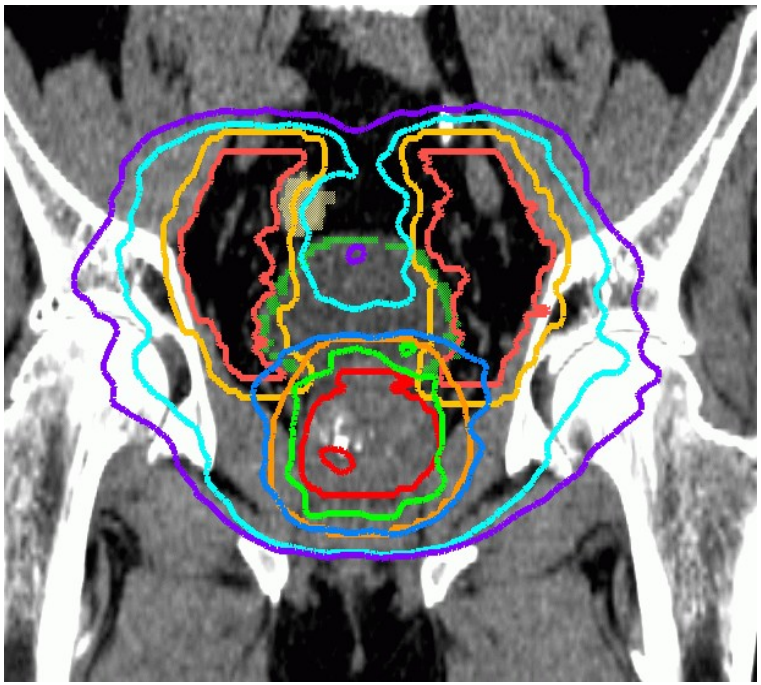

Y2
X1
Y1
Y2
X2
Y1

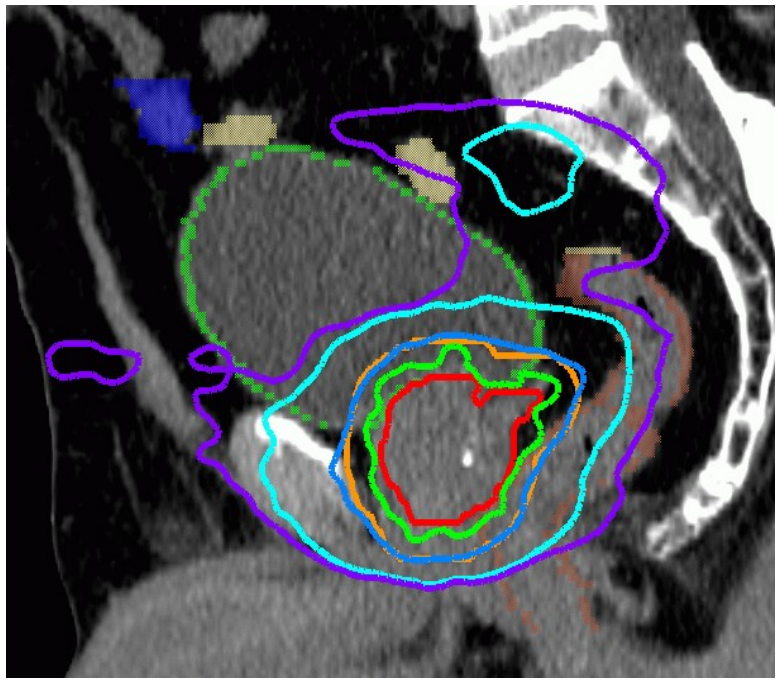
Dose Distribution



7700
7400
7030
4370
3700

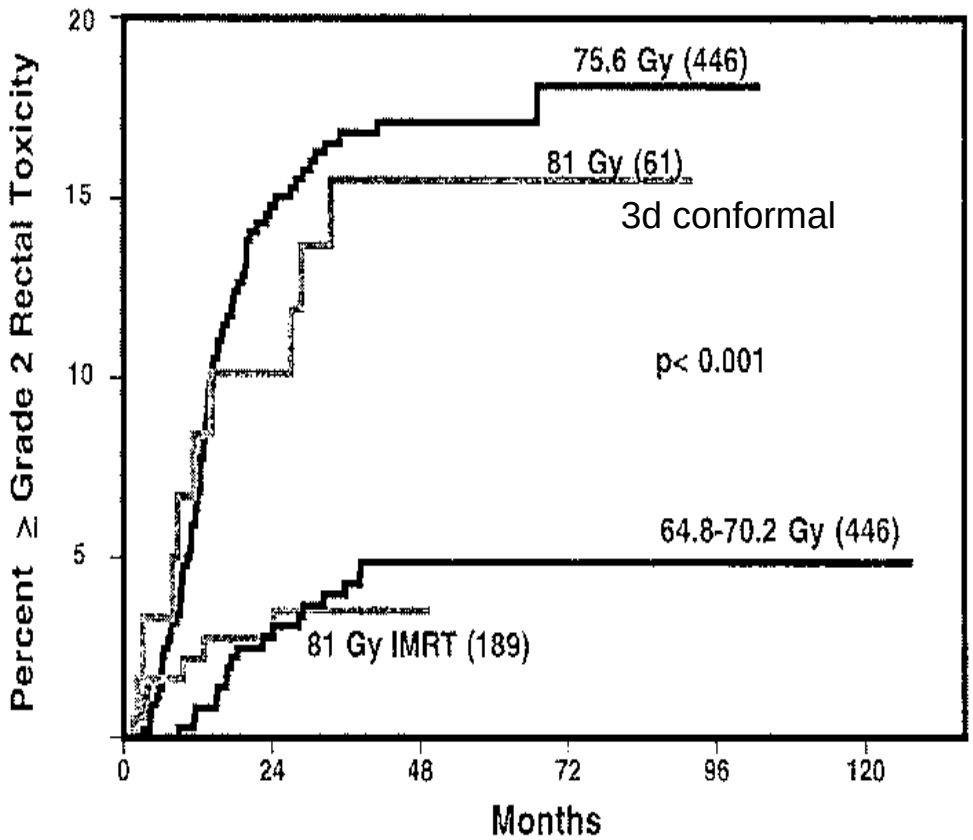
Dose Distribution





7700
7400
7030
4370
3700

Toxicity



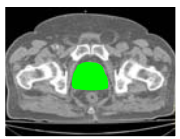
Zelefsky et al

Step-by-step process - Planning

Patient education + Prep instructions

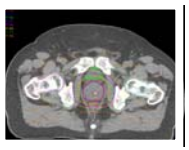
Immobilisation - VacLok

CTSim - 2mm slices for DRR generation



Contouring

PTV margin generation – 10mm (7mm post)



IMRT planning

Physics QA

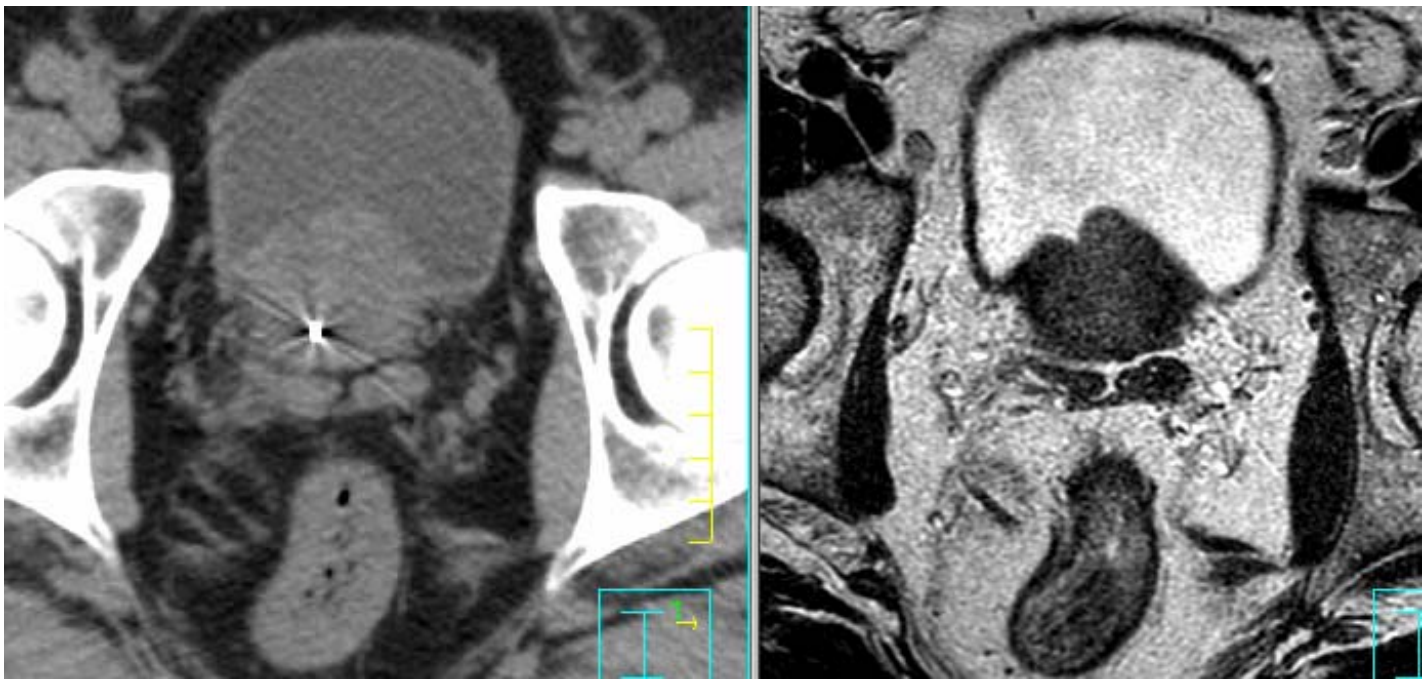
New technologies

- Planning RT
  - VMAT
- Tracking the prostate
  - GPS, soft tissue, US
- Improved imaging
  - MRI

High Precision Radiotherapy

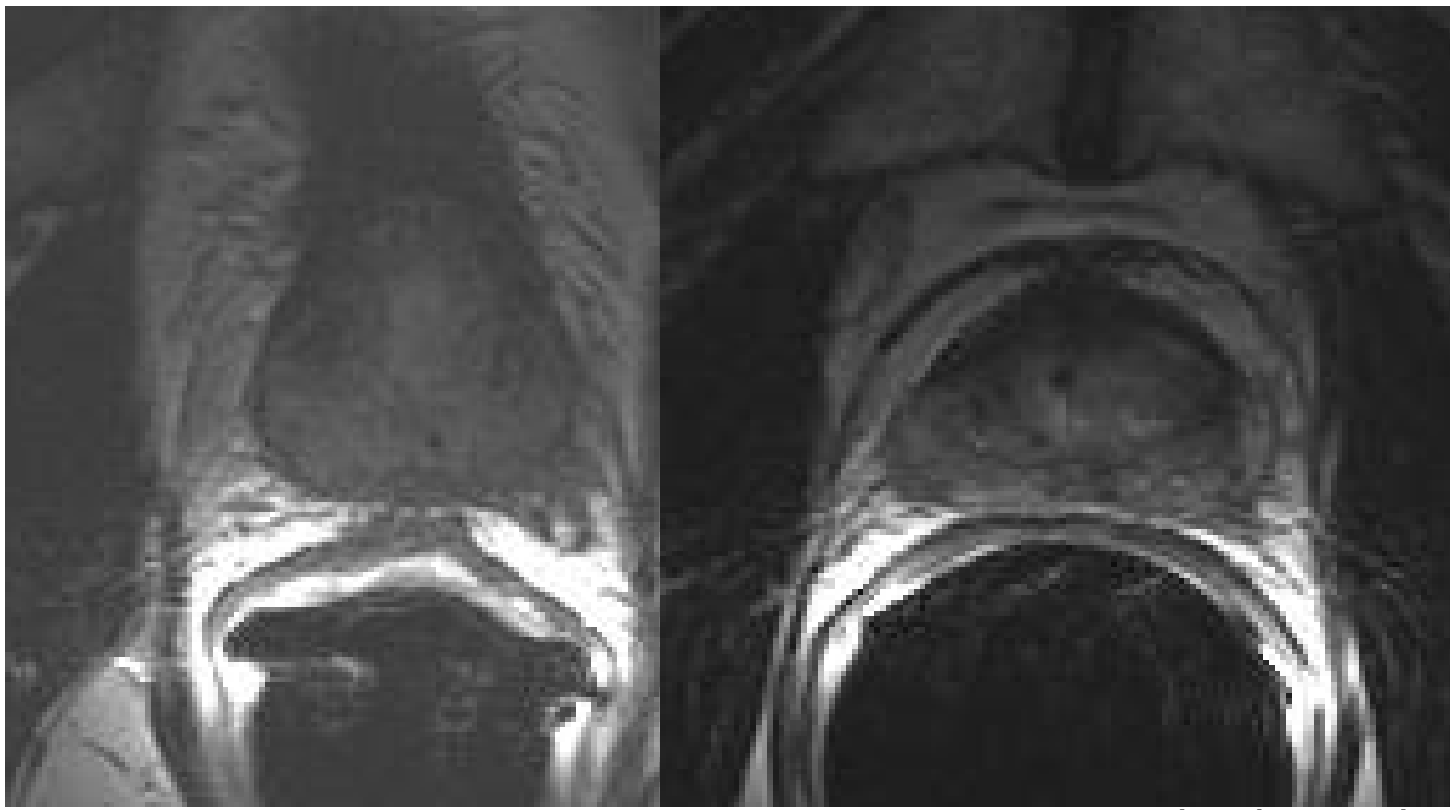
- Identifying the tumour
- Knowing where the tumour is during treatment
- Accurate targeting of the tumour

MRI



Extracapsular Extension

- Rectoprostatic angle



Choyke et al.

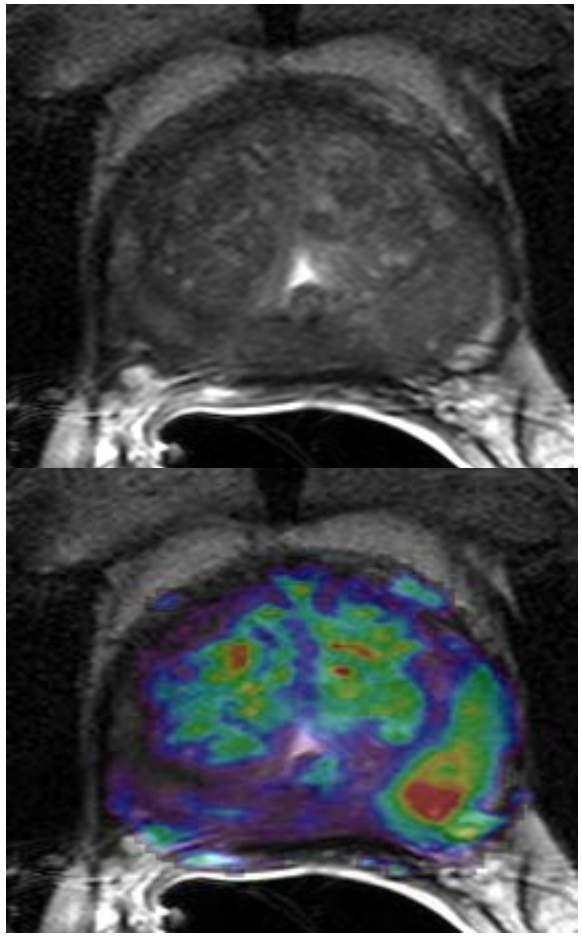
MRI Disease

- Low T2
- Fast T1 contrast enhancement & washout
- Low diffusivity
- High Choline / Citrate

Haider et al.

MRI Disease

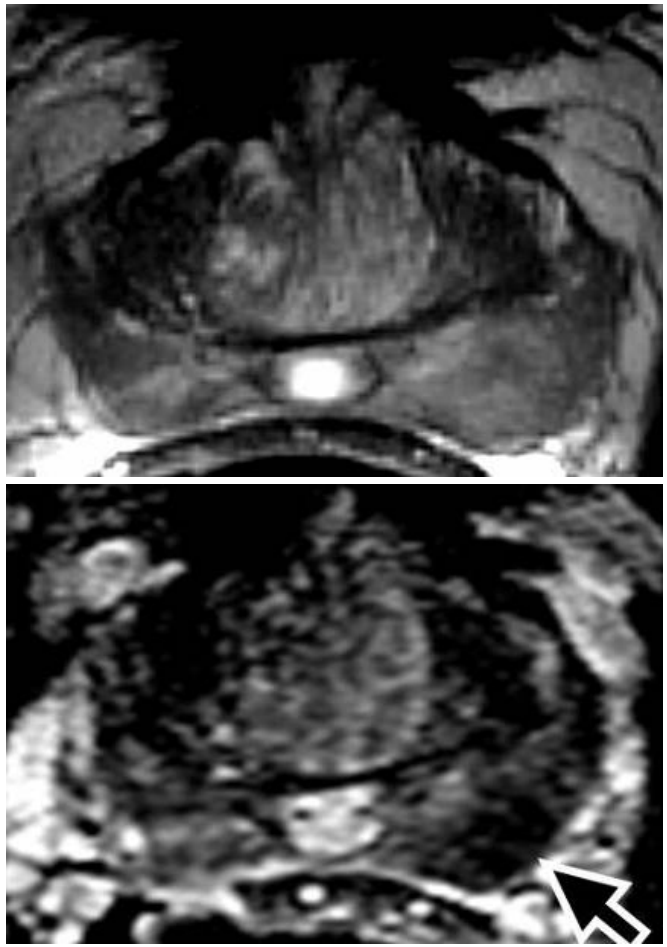
- Low T2
- Fast T1 contrast enhancement & washout
- Low diffusivity
- High Choline / Citrate



Choyke et al.

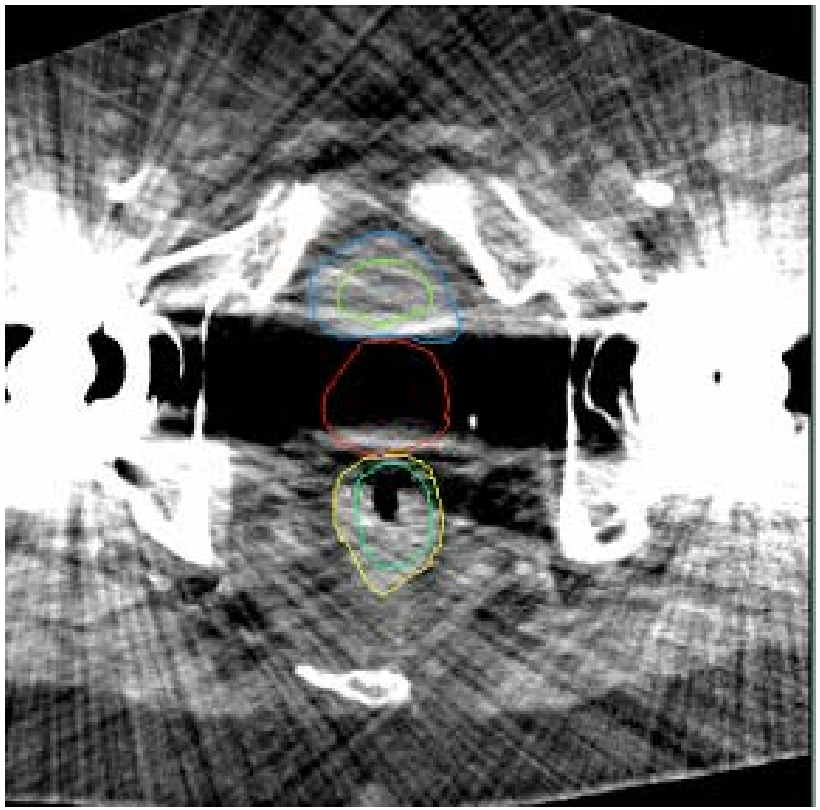
Disease

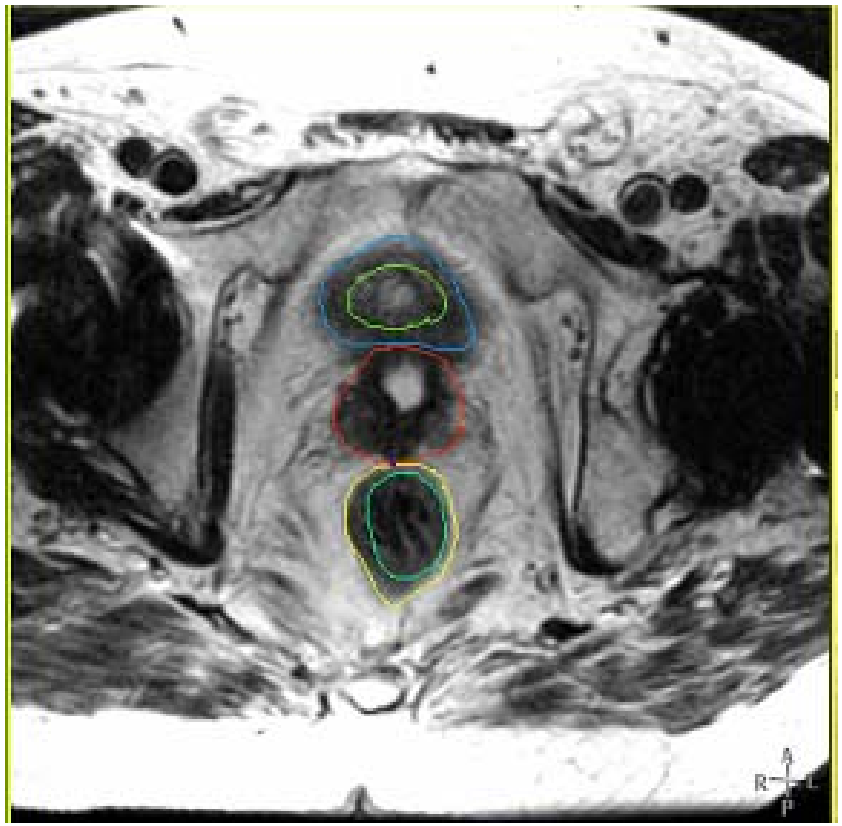
- Low T2
- Fast T1 contrast enhancement & washout
- Low diffusivity
- High Choline / Citrate



Haider et al.

Anatomic Resolution



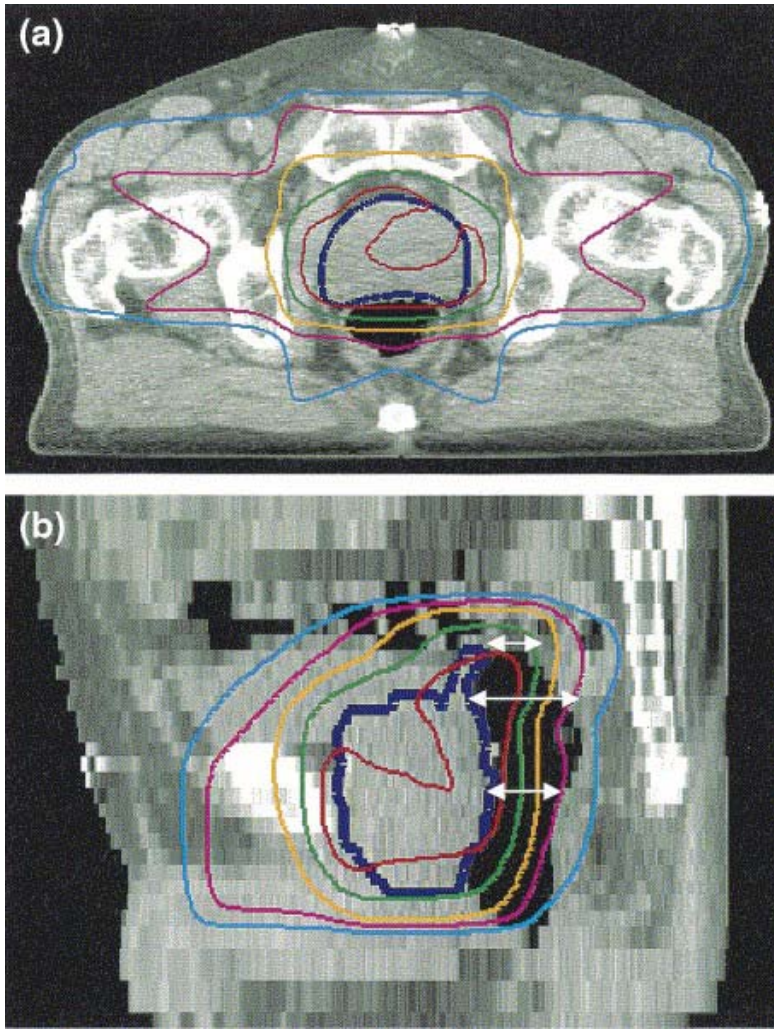


Rosewall et al.

Post-Prostatectomy

Ménard et al.

Missing the Target



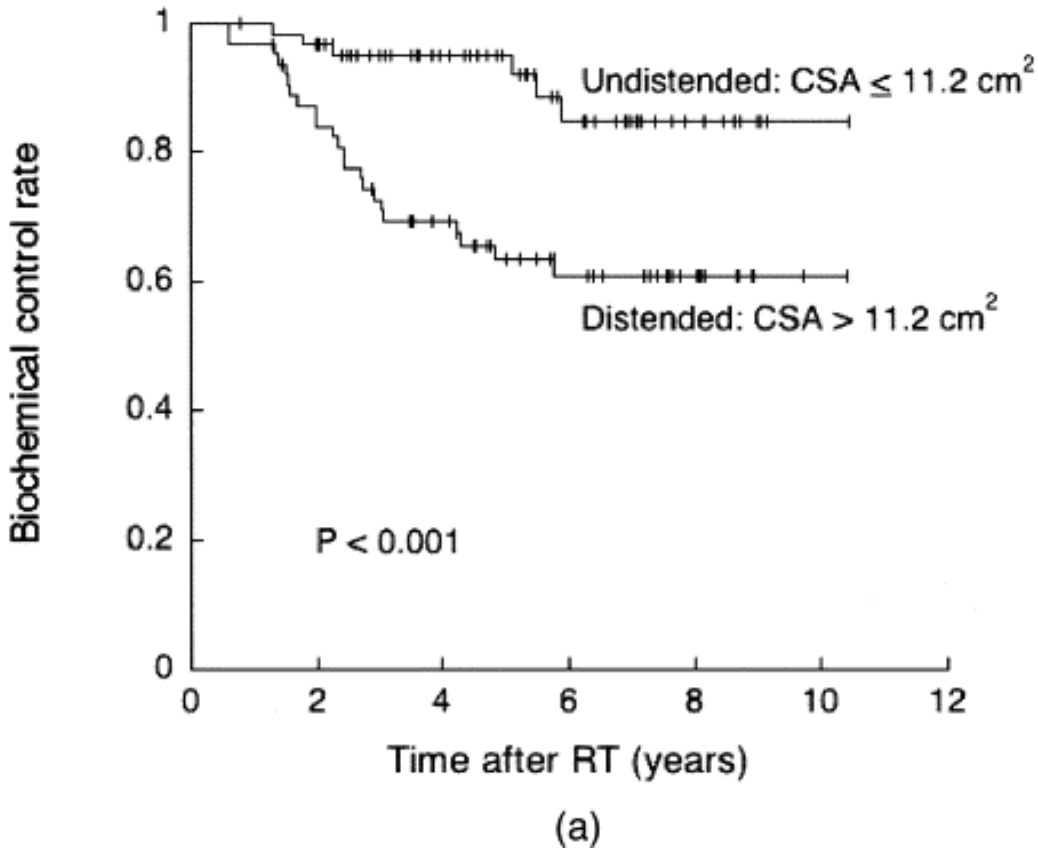
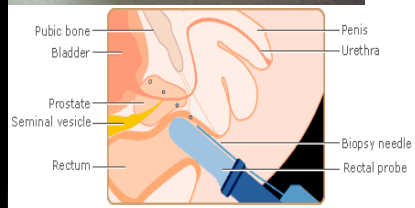


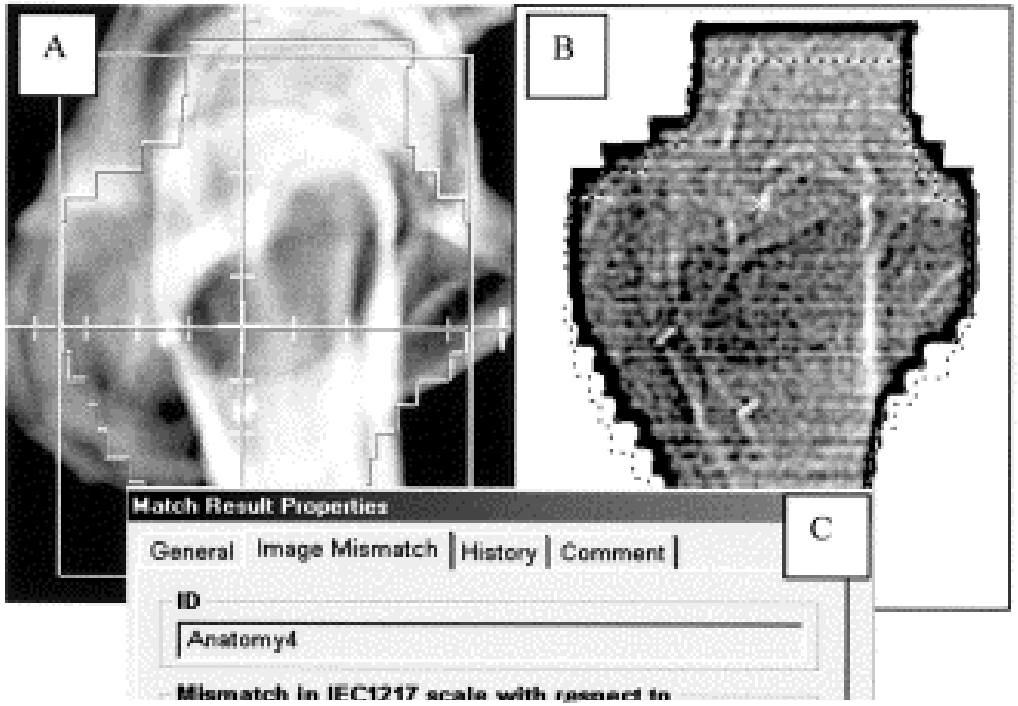
Image Guidance

- Accurately directing radiation to the target
- Improves precision
- Reduces normal tissue in the treatment volume

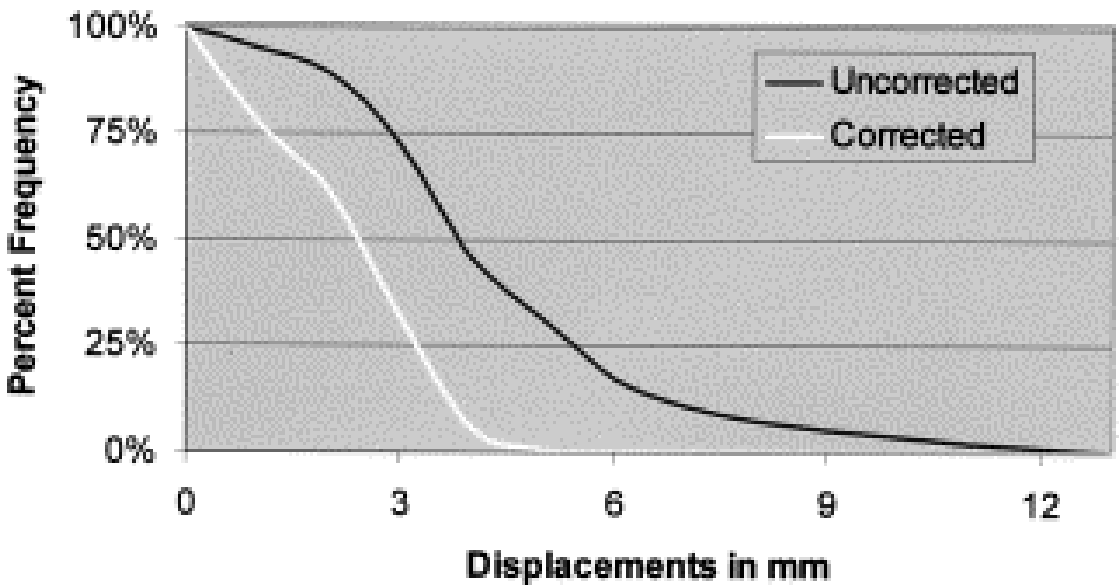
IMRT Prep

- Fiducial markers
- CT/MR simulation





2D Centre of Mass Displacements

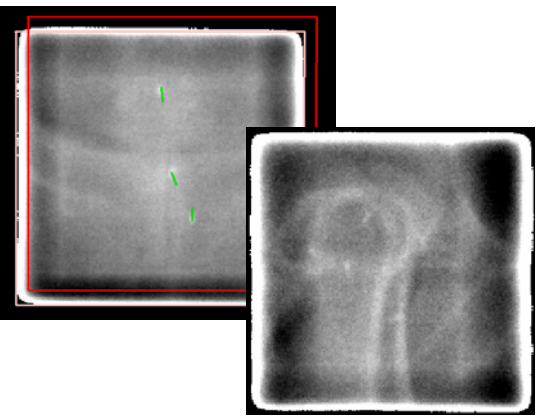


Action Level	Frequency
5mm	11%
3mm	19%
2mm	28%
1mm	38%

1st image to last beam	Mean time
Unadjusted	6.1 min (sd 1.3)
Adjusted	8.7 min (sd 2.3)

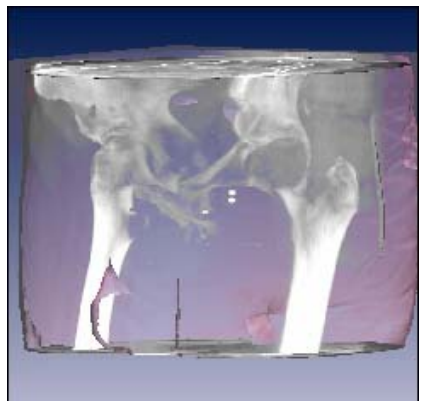
Chung et al

Cone beam CT



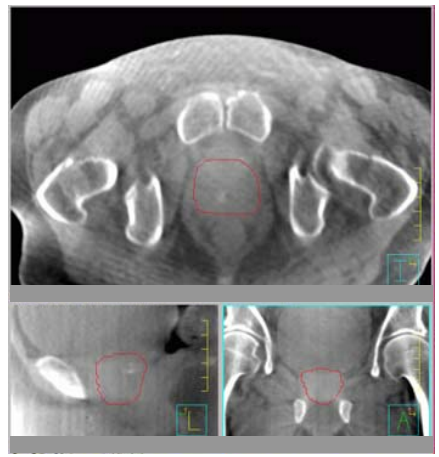
MV Markers:
Template matching

Vs



CBCT Markers:
Auto-segmentation

Vs



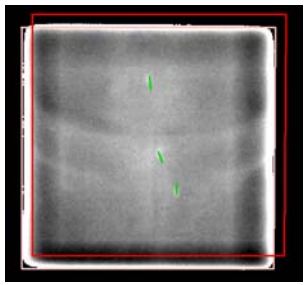
CBCT Soft Tissue:
Reference contour

Couch Shift: x,y,z

Moseley et al

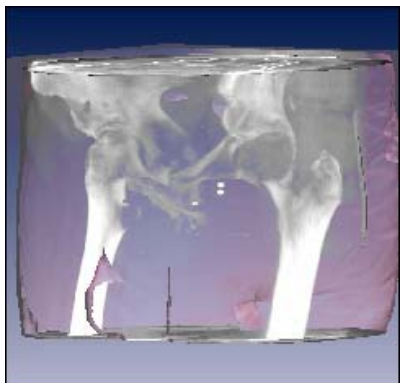
Results

	R/L	A/P	S/I
σ	= 0.58,	1.29,	1.27
Σ	= 0.35,	0.99,	0.98
Margin	1.3 mm	3.4	3.3



MV Markers

	R/L	A/P	S/I
σ	= 0.89,	2.24,	2.27
Σ	= 0.51,	2.22,	1.17
Margin	1.9 mm	7.1	4.5



CBCT Markers

$$2.5\,\Sigma + 0.7\,\sigma$$

van Herk's Margin Recipe

CBCT Soft Tissue


File Options Global 2D Help
2D 3D
Slice 1: X = 0.

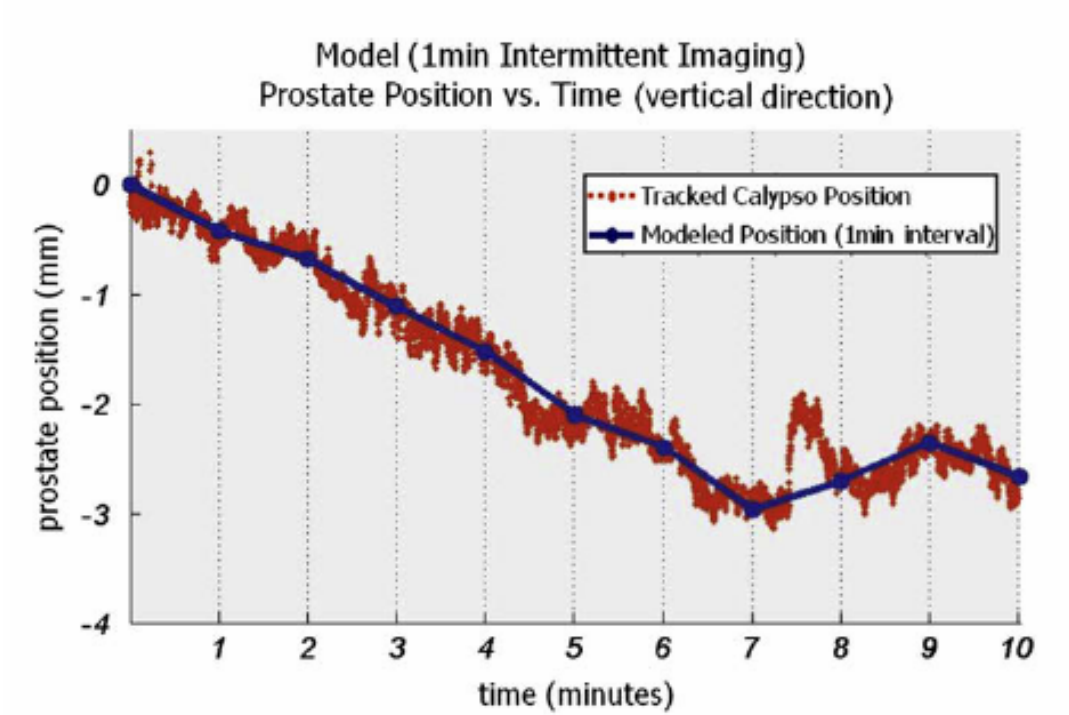
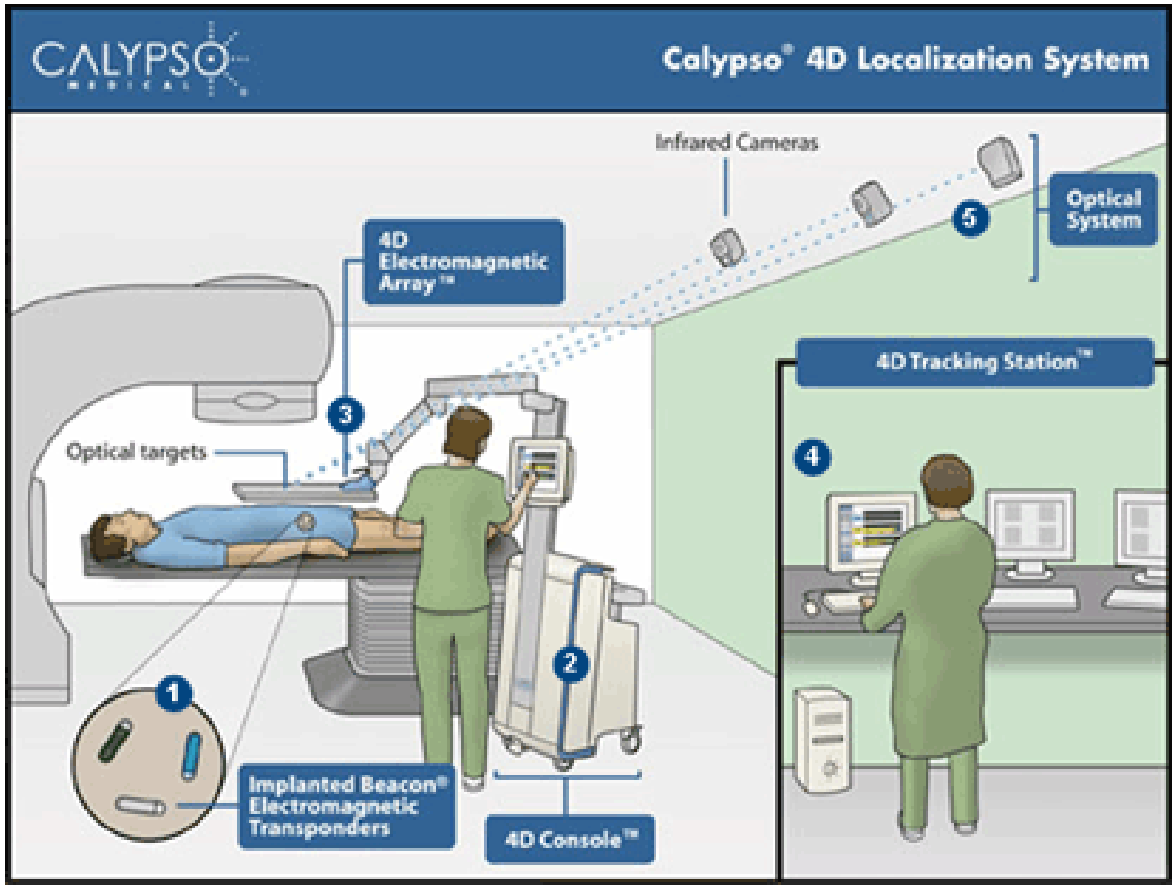
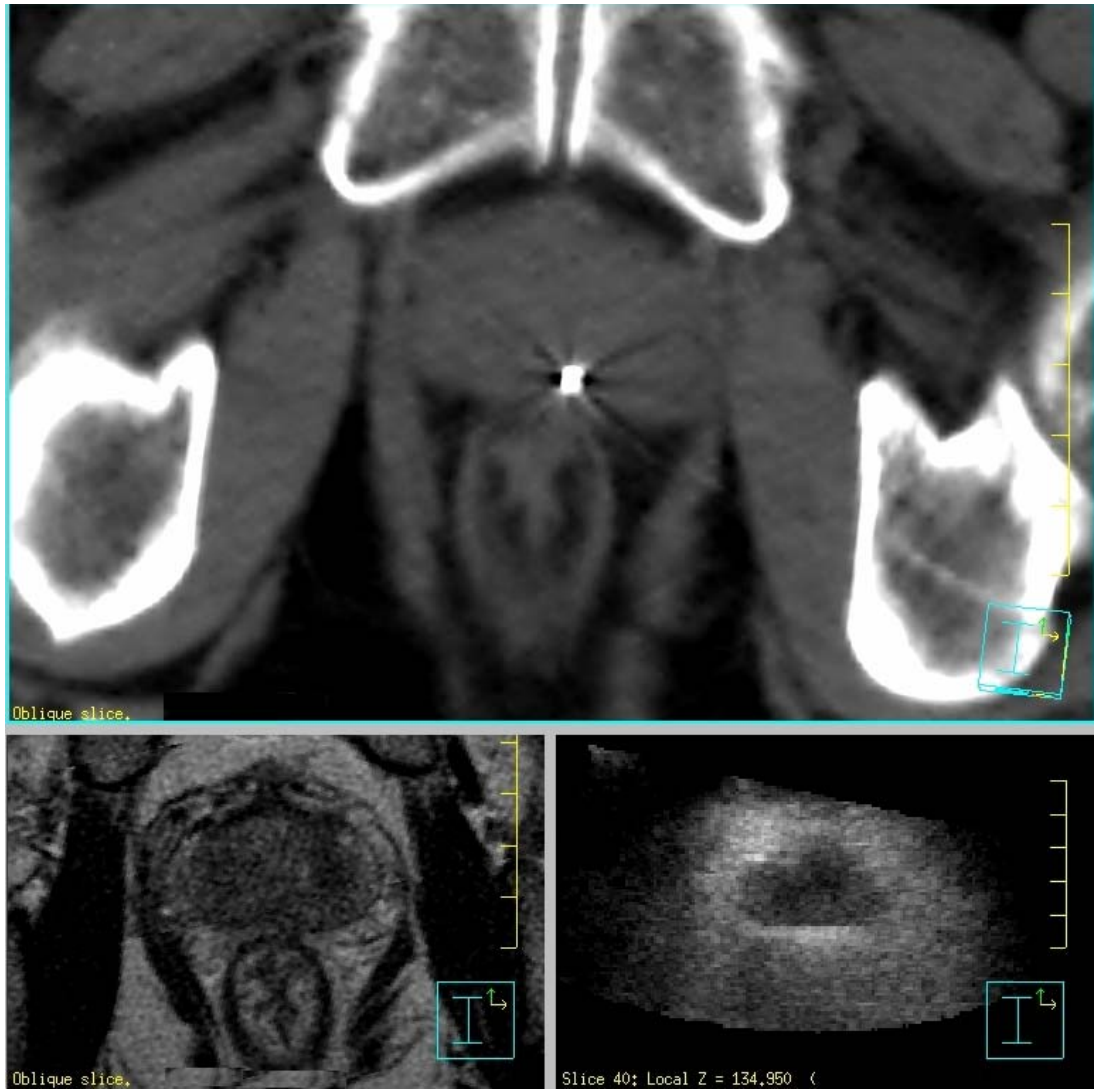


Fig. 3. Prostate motion over a single fraction as predicted by an intermittent imaging model with an imaging interval of 1 min and as actually tracked by the Calypso® System. (Only one dimension is shown; actual models are three-dimensional.)

Noel et al , 2009

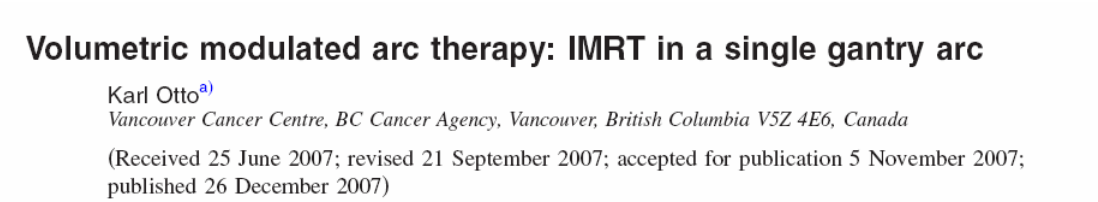

CALYPSO
MEDICAL
Calypso® 4D Localization System
Infrared Cameras
5
Optical System
4D Electromagnetic Array™
4D Tracking Station™
3
Optical targets
4
2
1
Implanted Beacon® Electromagnetic Transponders
4D Console™


Clarity
0.5 mm
LT
0.7 mm
ANT
1.4 mm
SUP


Oblique slice.
Oblique slice.
Slice 40; Local Z = 134.950 (

Volumetric Modulated Arc Therapy (VMAT)

- Continuous irradiation with gantry motion;
  - as in conventional arc therapy.
- Field shape changes with rotation;
  - "Arbitrary" fluence patterns at each gantry angle *fall within a single arc.*



Volumetric modulated arc therapy: IMRT in a single gantry arc

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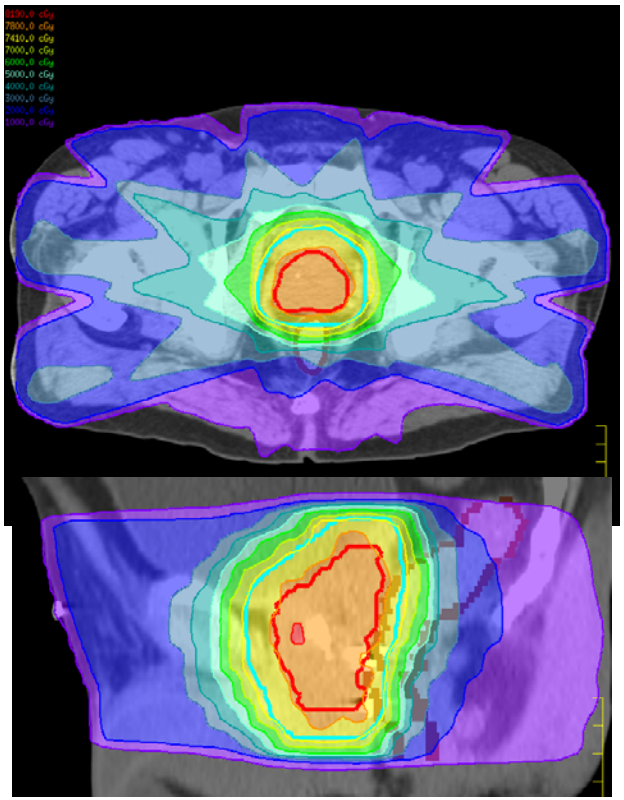
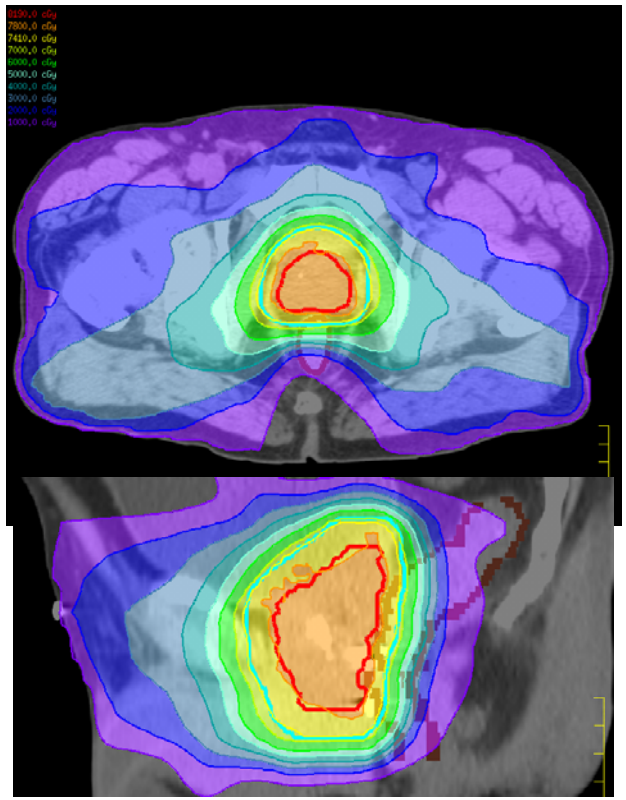
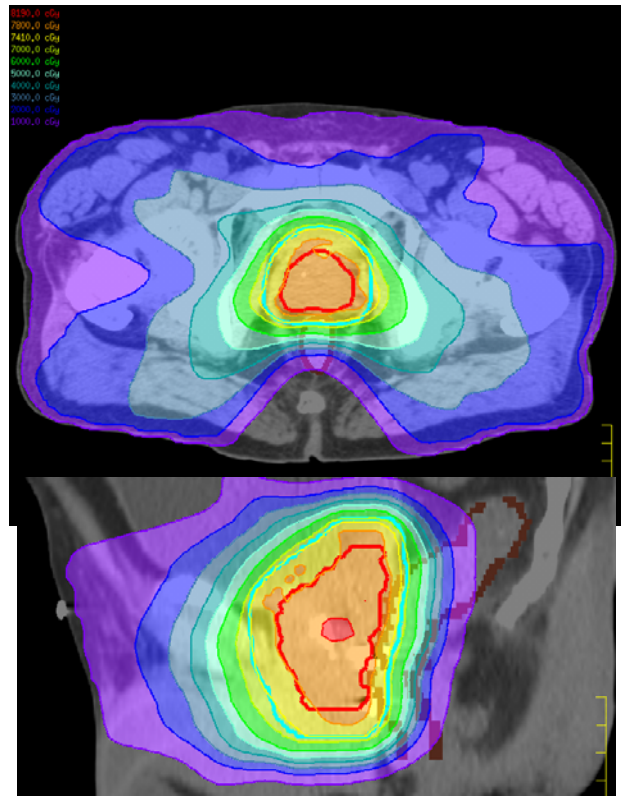
Otto et al



7 field
Step-and-Shoot
5.6 minutes
362 MU

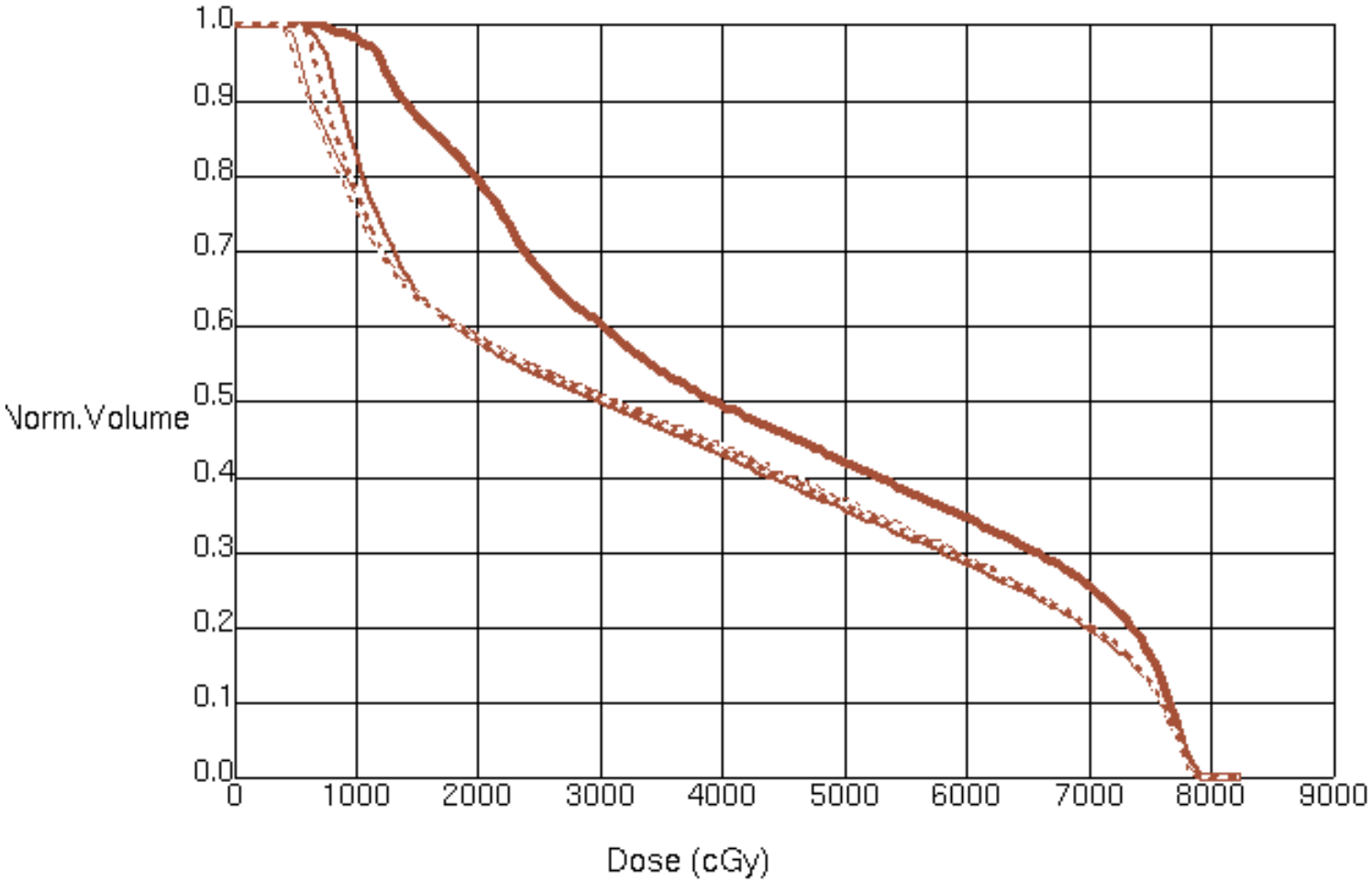


360 degree arc
VMAT
4.2 minutes
442 MU

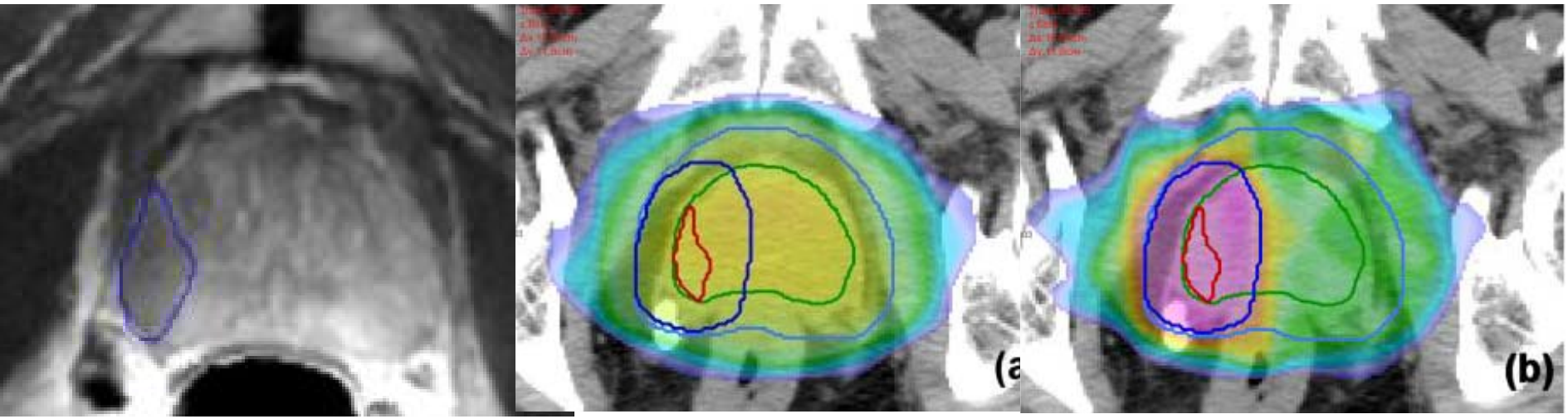


360 degree arc
VMAT
1.0 minutes
421 MU

Rectum DVH VMAT (dashed), S&S (solid)



Focusing on the Tumor



Conclusions

- Radiotherapy continues to evolve
- Dynamic process
- Old and new technologies continue to advance the ‘state of the art’
- Delivery of dose to a specified target with sparing of normal tissue as a goal is achievable…….we are not there…….yet

Acknowledgements

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Lorie Divanbeigi
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Team 3 Therapists