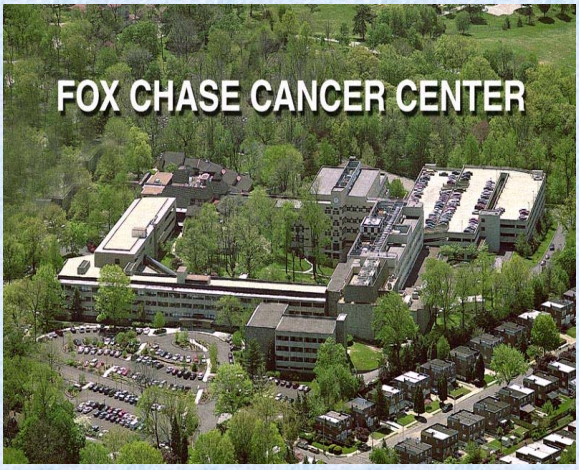
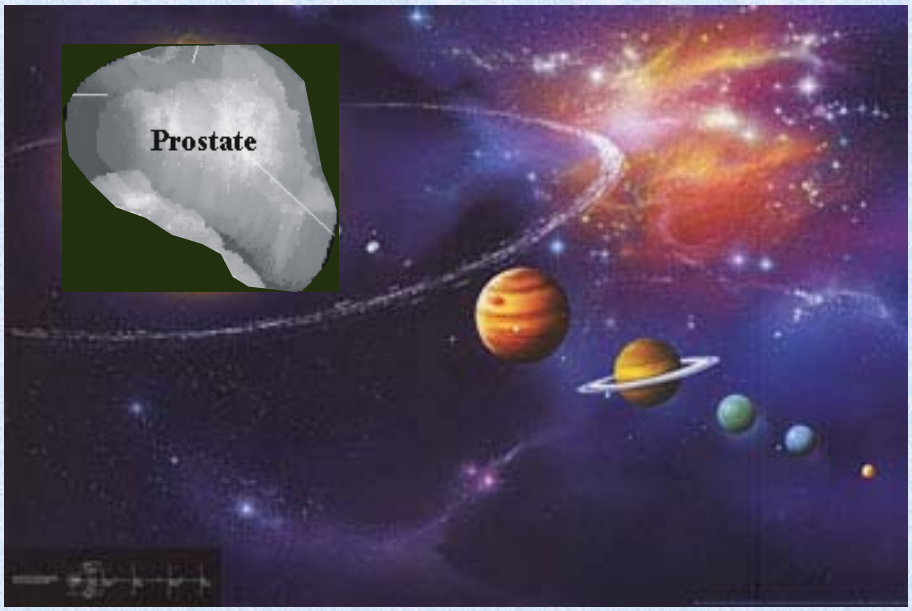
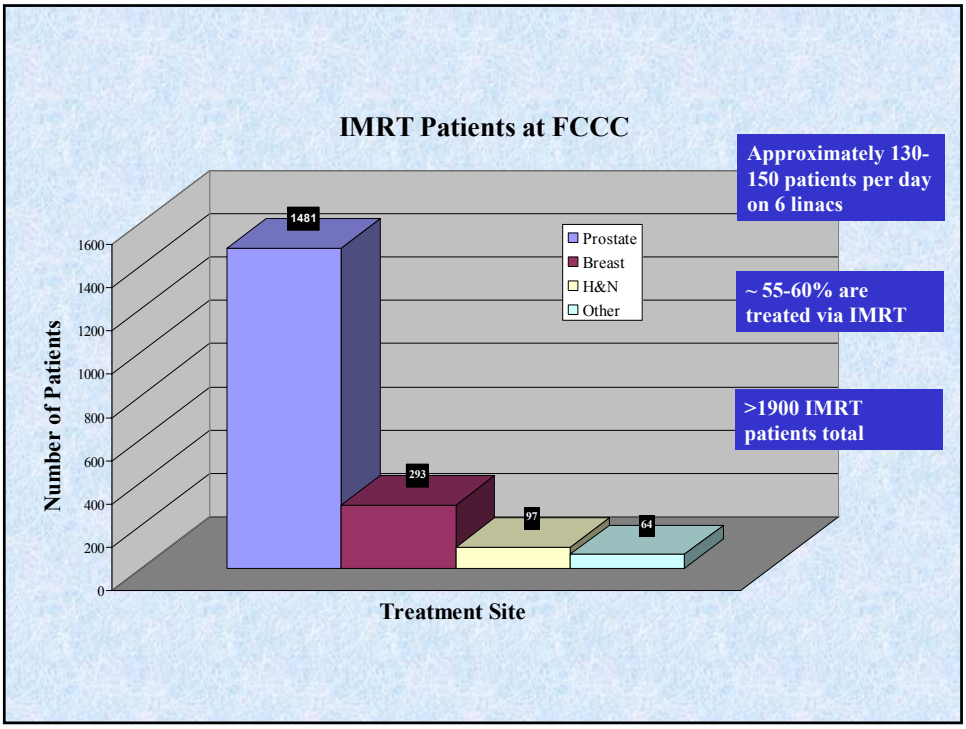
IMRT for Prostate Cancer



Robert A. Price Jr., Ph.D.
Philadelphia, PA

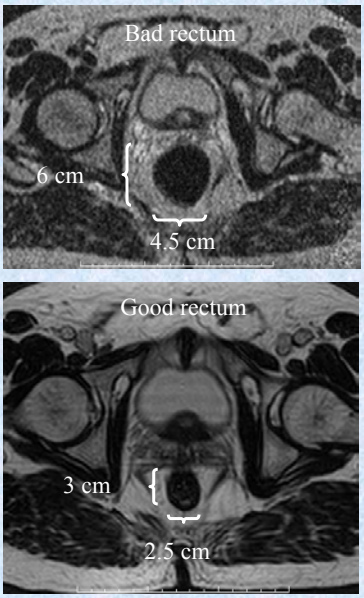




All patients are simulated in the supine position. Reproducibility is achieved using a custom alpha cradle cast that extends from the mid-back to mid-thigh. The feet are positioned in a custom plexiglas foot-holder. The patient is told to have a half-full bladder because during treatment a full bladder is difficult to maintain.

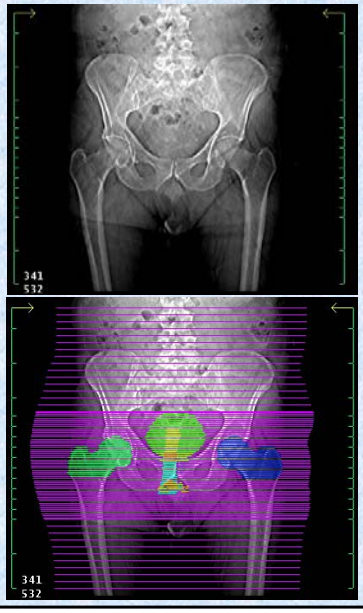
Simulation (Positioning and Immobilization)

- The patient is asked to empty the rectum using an enema prior to simulation. Also, a low residue diet the night before simulation is recommended to reduce gas. If at simulation the rectum is >3 cm in width due to gas or stool, the patient is asked to try to expel the rectal contents.



CT Scans

- Scans are acquired from approximately 2 cm above the top of the iliac crest to approximately mid-femur. This scan length will facilitate the use of non-coplanar beams when necessary.
- Scans in the region beginning 2 cm above the femoral heads to the bottom of the ischial tuberosities are acquired using a 3 mm slice thickness and 3 mm table increment. All other regions are scanned to result in a 1 cm slice thickness.



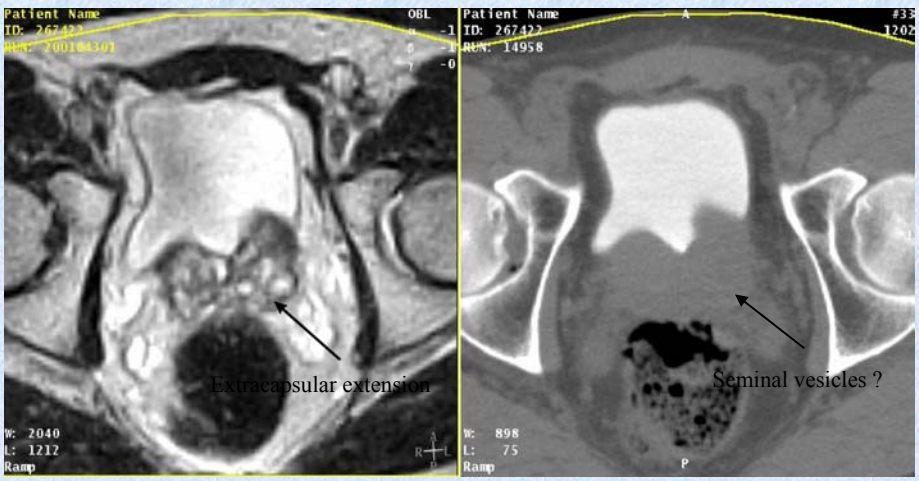
MR Scans

- All prostate patients also undergo MR imaging within the department, typically within one half hour before or after the CT scan. Scans are obtained ***without*** contrast media. The resultant images are processed using a gradient distortion correction (GDC) algorithm.
- CT and MR (after GDC) images are fused according to bony anatomy using either chamfer matching or maximization of mutual information methods. ***All soft tissue structures are contoured based on the MR information while the external contour and bony structures are based on CT.***

0.23 T, Philips Medical Systems

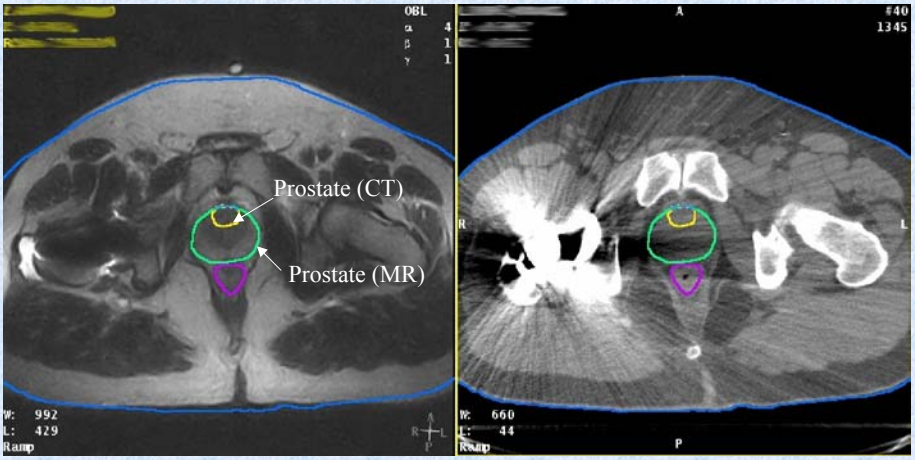
•Retrograde urethrograms are ***not*** performed.

MRI CT

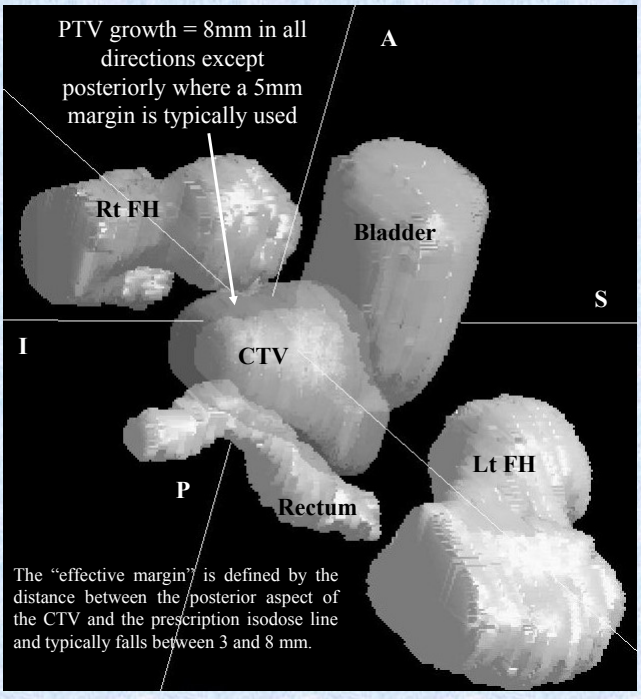


Imaging modality may affect treatment regime

MRI CT



Imaging artifacts may affect contouring



Acceptance Criteria

DVH Acceptance Criteria

$PTV_{95\ \%} \geq 100\%$ Rx

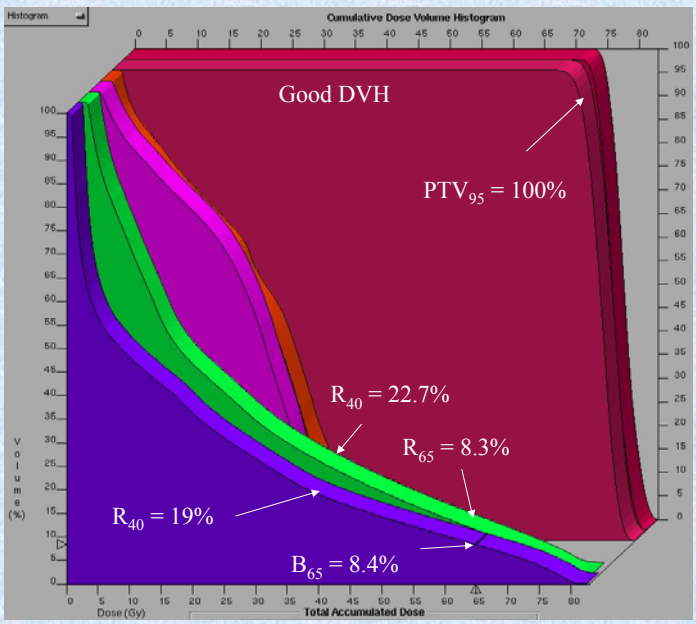
$R_{65\ Gy} \leq 17\%V$

$R_{40\ Gy} \leq 35\%V$

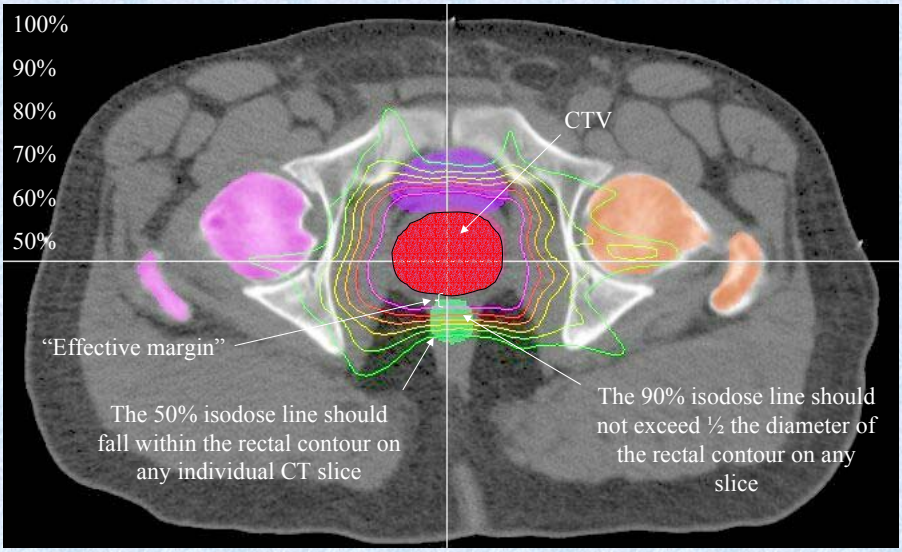
$B_{65\ Gy} \leq 25\%V$

$B_{40\ Gy} \leq 50\%V$

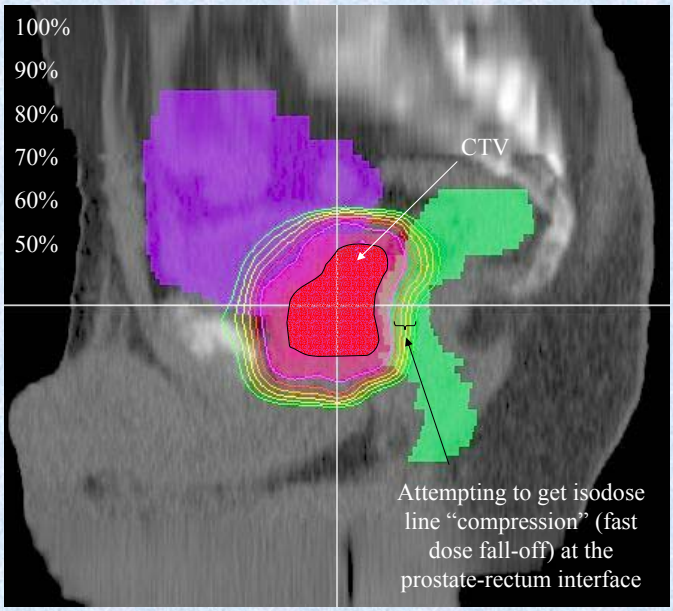
$FH_{50\ Gy} \leq 10\%V$



Good plan example (axial)



Good plan example (sagital)



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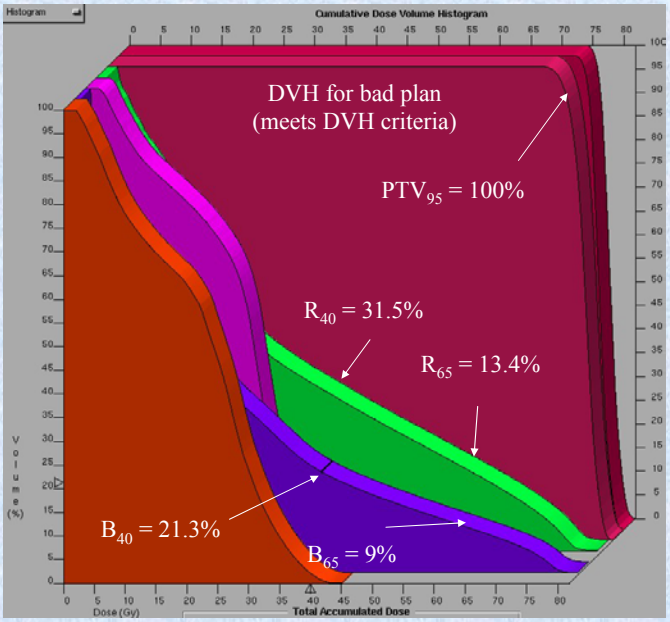
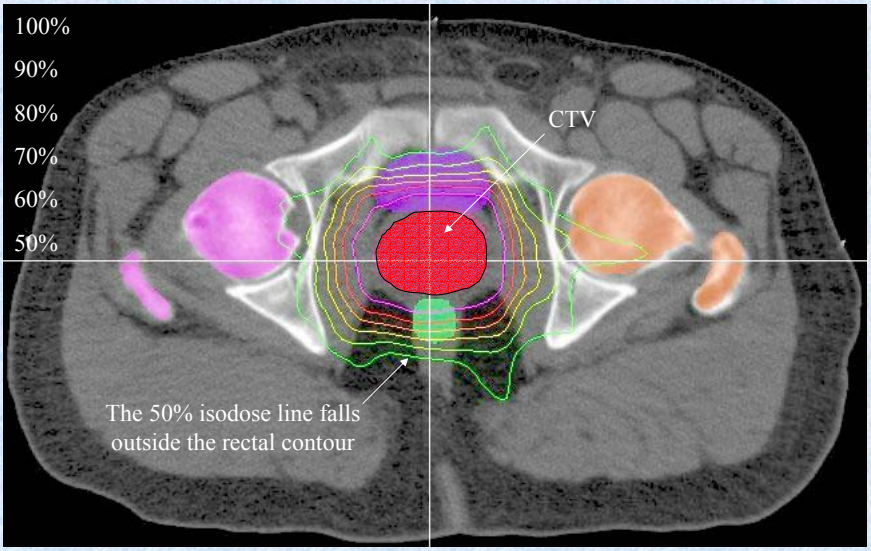
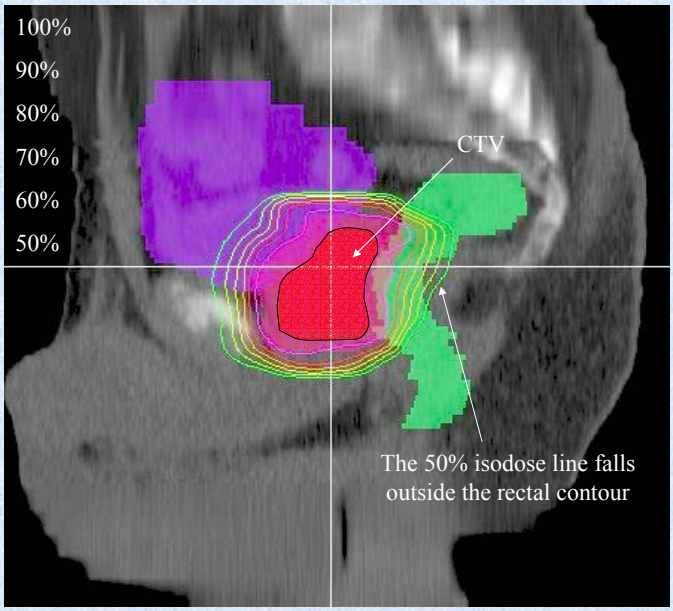


Bad plan example (axial)



Bad plan example (sagital)



Typical Dose

Routine treatments

- Prostate + proximal sv (76 Gy @ 2.0 Gy/fx)
- Distal sv, lymphatics (56 Gy @ ~1.5 Gy/fx)
- 38 fractions total

Post Prostatectomy

- Prostate bed (64-66 Gy @ 2.0 Gy/fx)

Hypofractionation

- Prostate + proximal sv (70.2 Gy @ 2.7 Gy/fx) **equivalent to 84.4 Gy in 2 Gy fractions assuming an α/β ratio of 1.5.**
- Distal sv, lymphatics (50 Gy @ ~1.5 Gy/fx)
- 26 fractions total

BED for rectum & bladder

$R_{50\ Gy} \leq 17\%V$

$R_{31\ Gy} \leq 35\%V$

$B_{50\ Gy} \leq 25\%V$

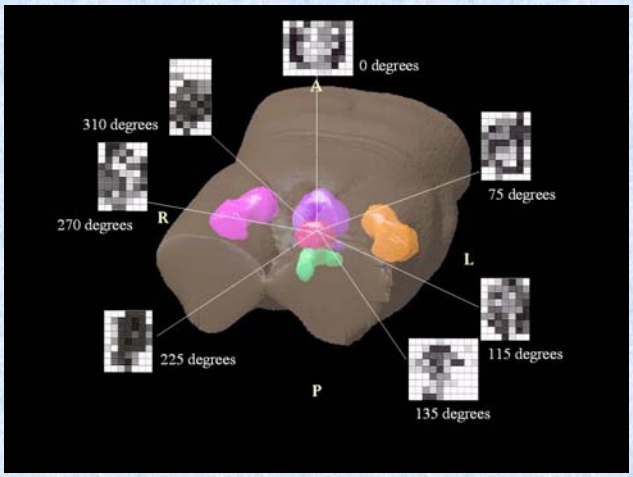
$B_{31\ Gy} \leq 50\%V$

$FH_{40\ Gy} \leq 10\%V$

Number of Beam Directions

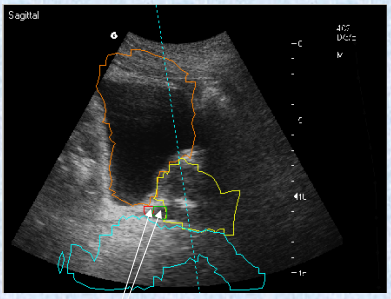
In the interest of delivery time we typically begin with 6 and progress to ≤ 9

Simpler plans such as prostate only or prostate + seminal vesicles typically result in fewer beam directions than with the addition of lymphatics



Localization

BAT Alignment

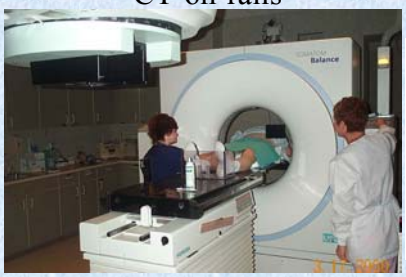


Separation of seminal vesicles into proximal and distal

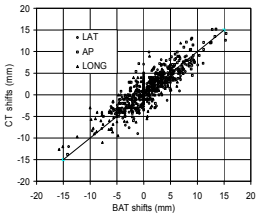
This has allowed for increased accuracy. Patient scans randomly evaluated; 303 prior to and 310 after technique adopted. Evaluated by same physician. Substandard alignments dropped from 15.1% to 3.5% (p=0.006)

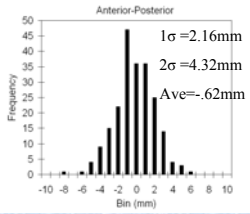
-McNeeley et al. AAPM 2004

"CT-on-rails"

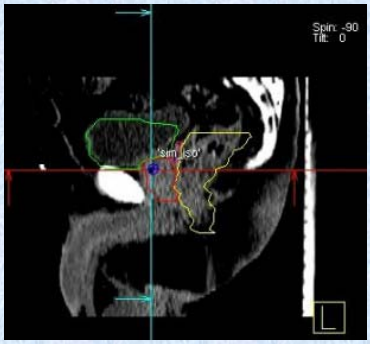


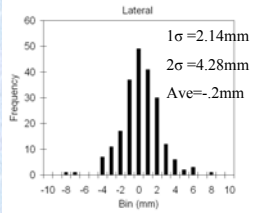
Prostate

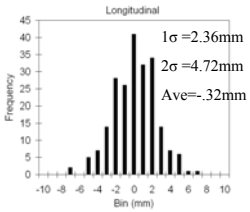




BAT vs. Primatom shifts. Data for 218 alignments are presented (differences between the 2 sets of shifts). The solid line is the line of perfect agreement between the two systems.

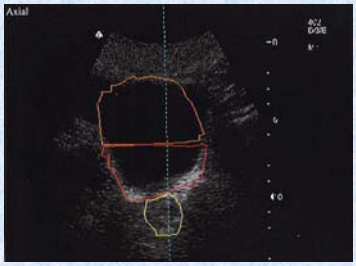




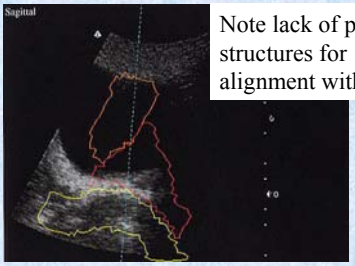


Feigenberg et al. (submitted)

Prostate Bed

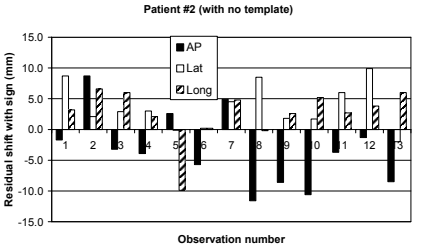


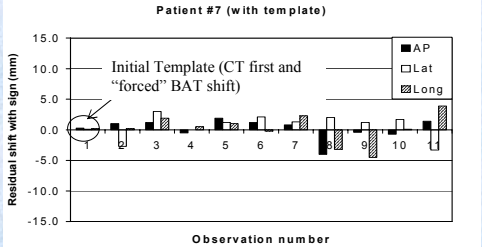
BAT first, CT second



Note lack of physical structures for alignment with BAT

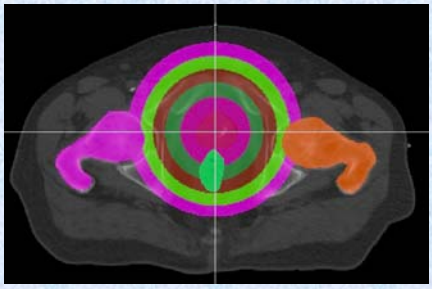
BAT first, CT second (Mon, Thurs, Mon…)





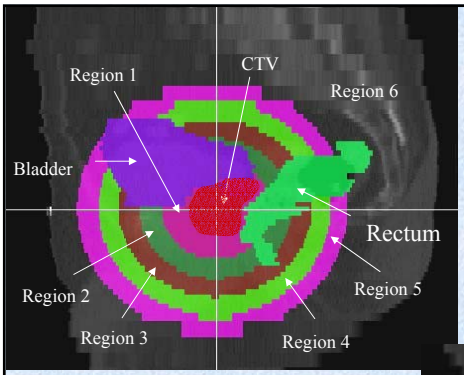
Paskalev et al. (In Press)

Regions for dose constraint

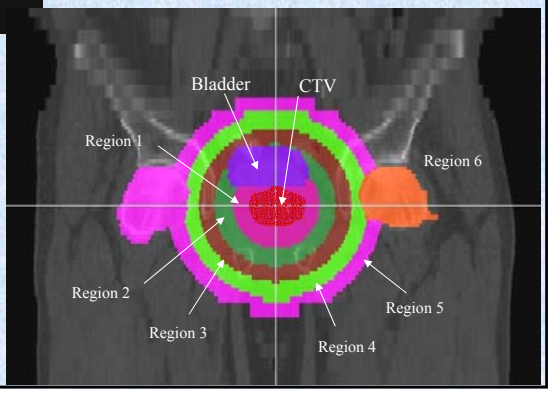


Region	Limit	% volume ↑ limit	Minimum	Maximum
1	90% of target goal	20	45% of target goal	Target Max
2	80%	20	40%	90% of target goal
3	70%	20	35%	75%
4	50%	1	25%	55%
5	30%	1	15%	35%
6	20%	1	10%	25%

Price et al. IJROBP 2003

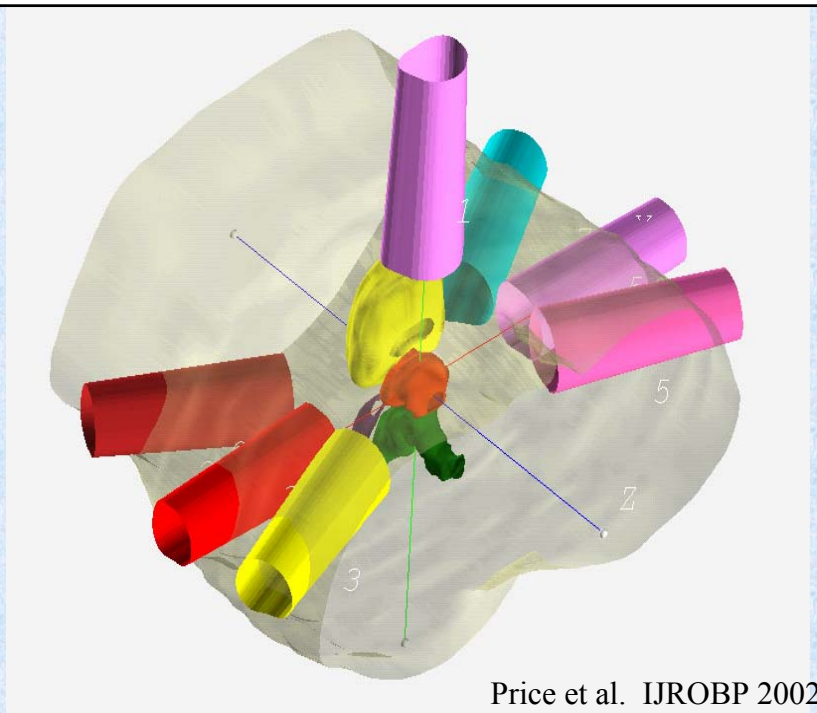


Attempt to assure that "PTV" will be encompassed by the 1st region

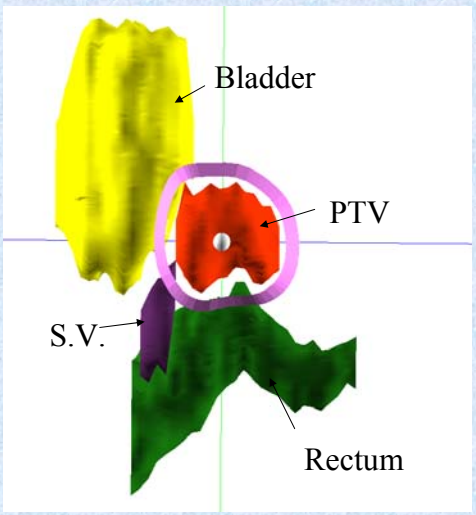


Regions

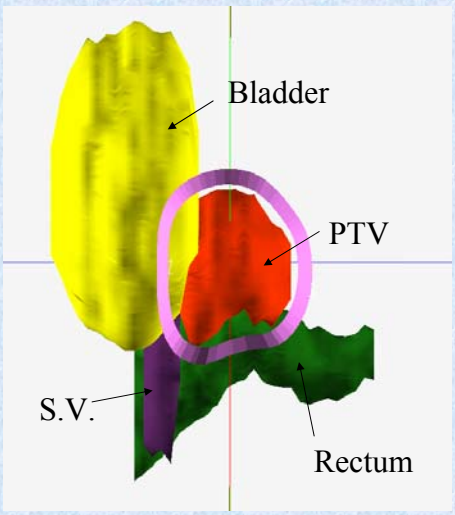
- 26 previously treated patients (6 and 10 MV)
- The average number of beam directions decreased by 1.62 with a standard error (S.E.) of 0.12.
- The average time for delivery decreased by 28.6% with a S.E. of 2.0% decreasing from 17.5 to 12.3 minutes
- The amount of non-target tissue receiving D_{100} decreased by 15.7% with a S.E. of 2.4%
- Non-target tissue receiving $D_{95,}$ $D_{90,}$ D_{50} decreased by 16.3, 15.1, and 19.5%, respectively, with S.E. values of approximately 2%



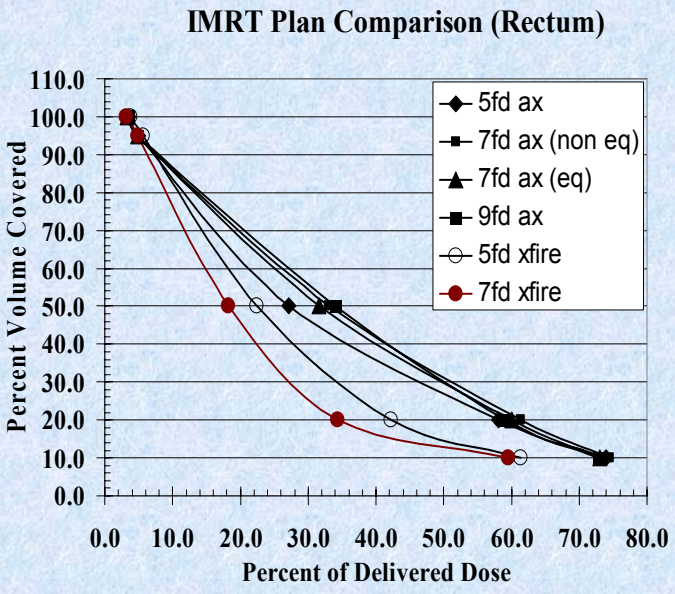
Price et al. IJROBP 2002



Direct right lateral



Anterior 45 degree oblique



Nodal Irradiation

Phase III Trial Comparing Whole-Pelvic Versus Prostate-Only Radiotherapy and Neoadjuvant Versus Adjuvant Combined Androgen Suppression: Radiation Therapy Oncology Group 9413

By M. Roach III, M. DeSilvio, C. Lawton, V. Uhl, M. Machtay, M.J. Seider, M. Rotman, C. Jones, S.O. Asbell, R.K. Valicenti, S. Han, C.R. Thomas Jr, and W.S. Shipley

JCO 21:1904-1911, 2003

The inclusion of pelvic lymphatic irradiation in the treatment of prostate cancer for some patients has been suggested in RTOG 9413.

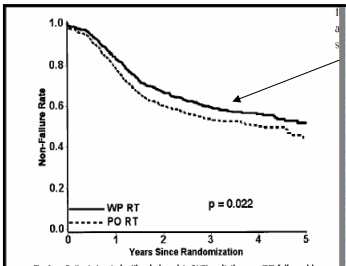


Fig 1. Patients treated with whole-pelvic (WP) radiotherapy (RT) followed by a boost to the prostate experienced a 4-year progression-free survival (PFS) of 54.2% compared with 47% in patients treated with prostate only (PO) RT (P = .022).

WP followed by prostate boost

Hormonal therapy and WP

PSA control

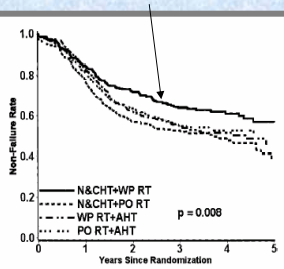


Fig 3. Four-year progression-free advantage for whole pelvic (WP) radiotherapy (RT) and neoadjuvant and concurrent hormonal therapy (NCHT)compared with prostate only (PO) RT and NCHT, and WP RT or PO RT and adjuvant hormonal therapy (AHT; 60 v 44, 49% and 50% respectively, P = .008).

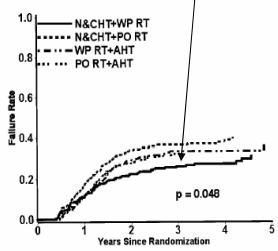


Fig 4. Prostate-specific antigen (PSA) control favors whole-pelvic (WP) radiotherapy (RT) and neoadjuvant and concurrent hormonal therapy (NCHT) compared with prostate only (PO) RT and NCHT, and WP RT or PO RT adjuvant hormonal therapy (AHT; P = .048).

Roach et al, RTOG 94-13

Targeting Progression

Intermediate risk (group 1)

PTV = prostate + proximal sv

High risk (group 2)

PTV1 = prostate + proximal sv

PTV2 = distal sv (no lymph nodes)

High risk (group 3)

PTV1 = prostate + proximal sv

PTV2 = distal sv

PTV3 = periprostatic + peri sv LNs

High risk (group 4)

PTV1 = prostate + proximal sv

PTV2 = distal sv

PTV3 = periprostatic + peri sv LNs

+ LN ext

High risk (group 5)

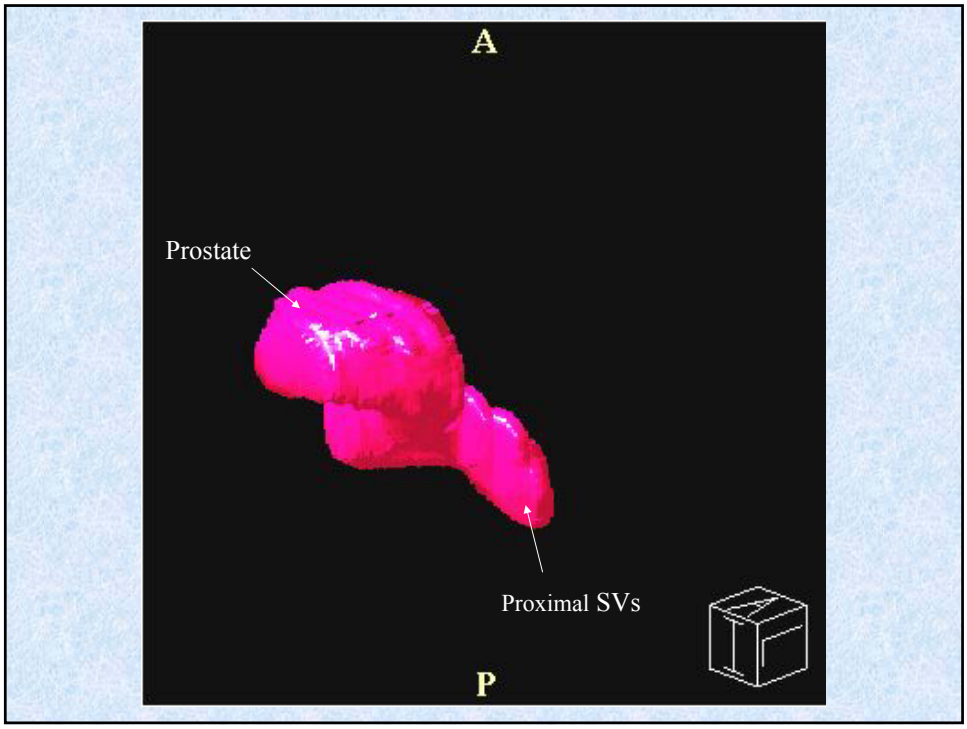
PTV1 = prostate + proximal sv

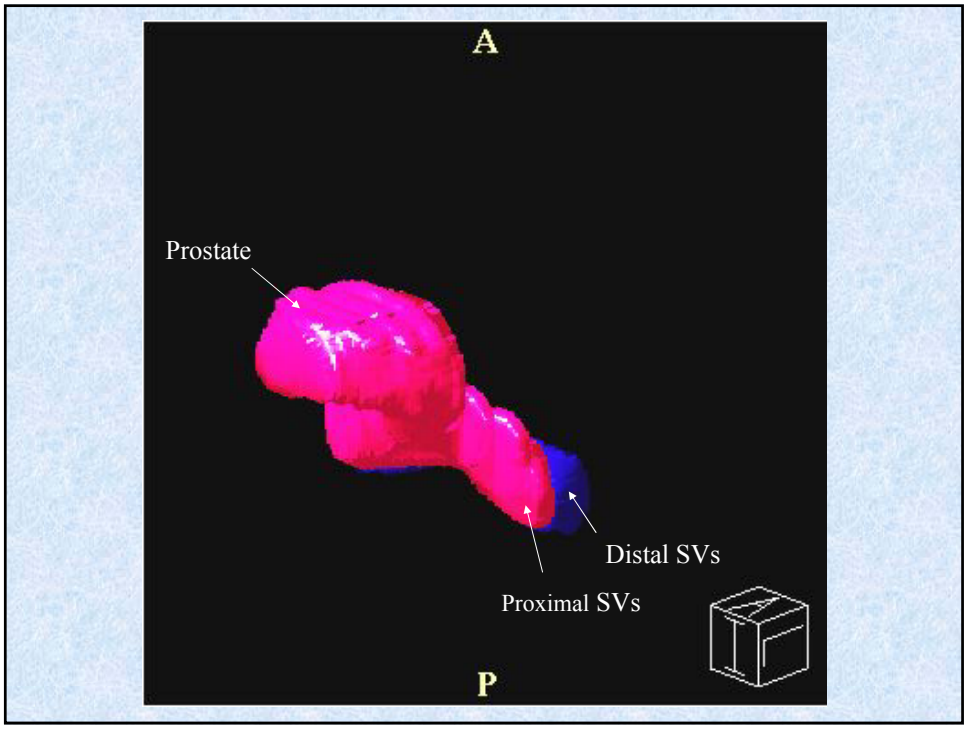
PTV2 = distal sv

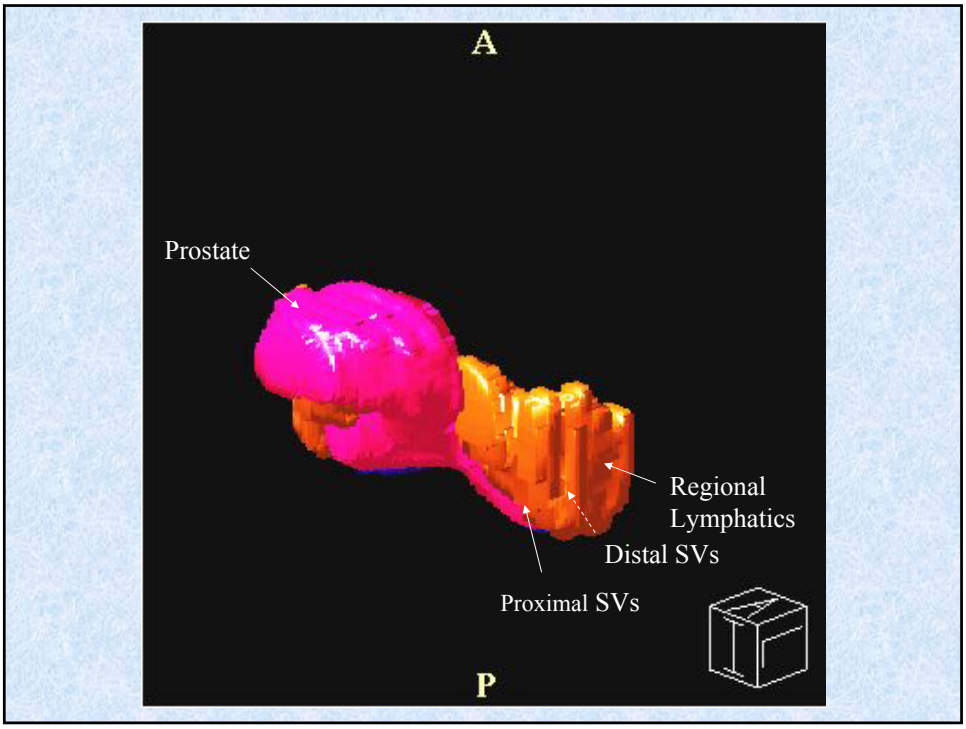
PTV3 = periprostatic + peri sv LNs + LN ext

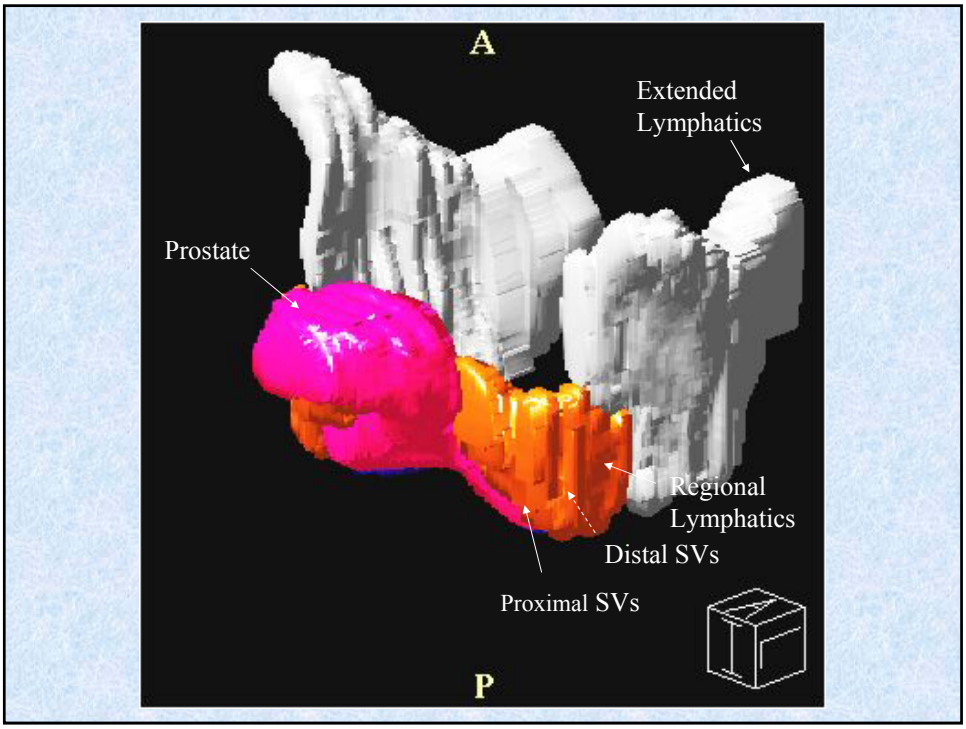
+ presacral LN

LN ext = external iliac, proximal obturator and proximal internal iliac


A
Prostate
Proximal SVs
P


A
Prostate
Distal SVs
Proximal SVs
P


A
Prostate
Regional
Lymphatics
Distal SVs
Proximal SVs
P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Extended
Lymphatics
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Regional
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Distal SVs
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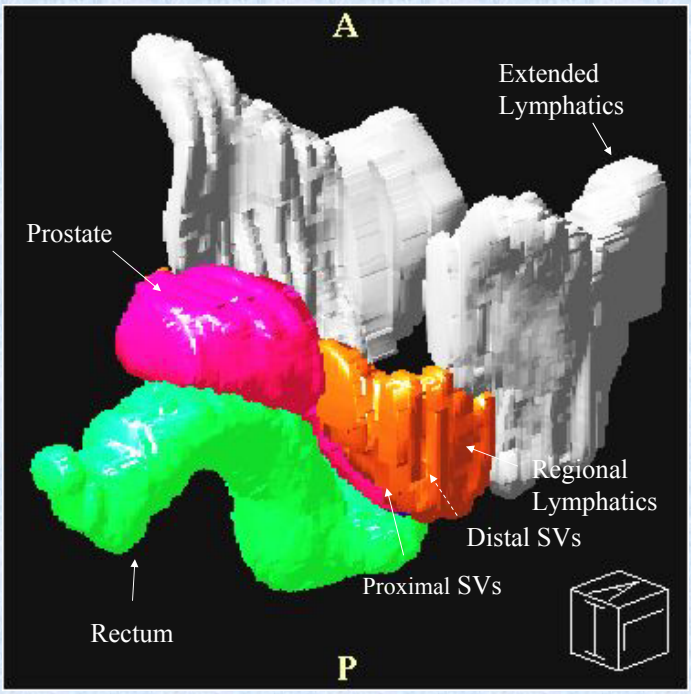
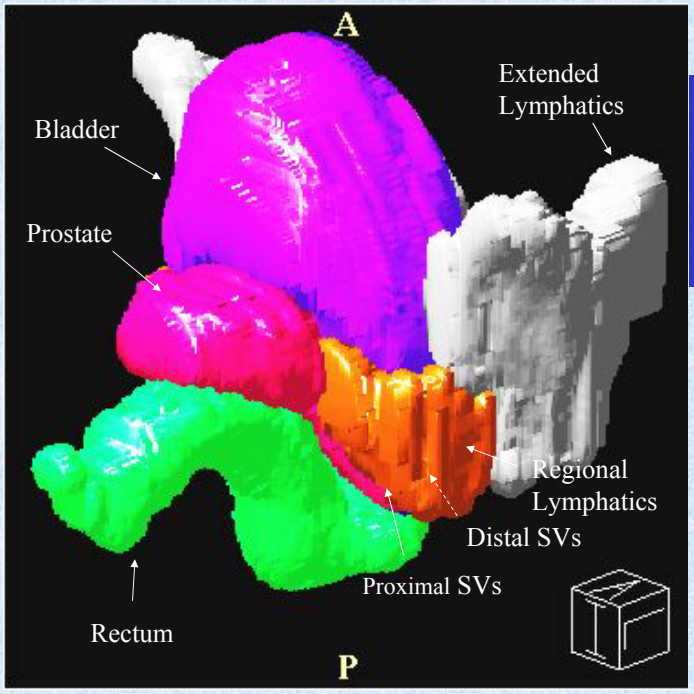
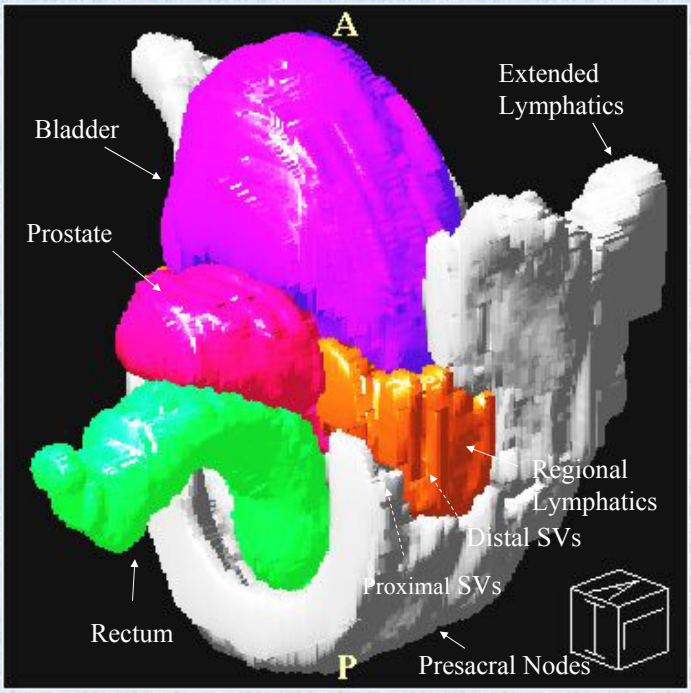
P





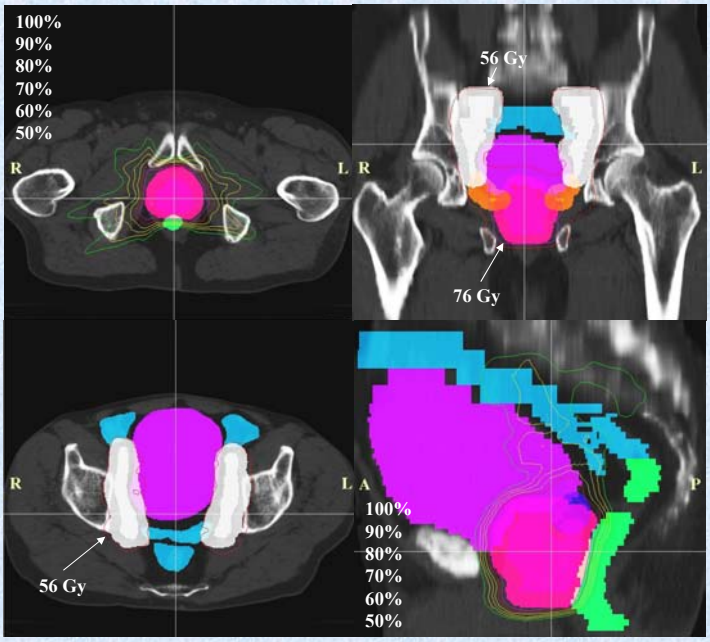
No longer a geometry problem; avoidance is only minimally useful



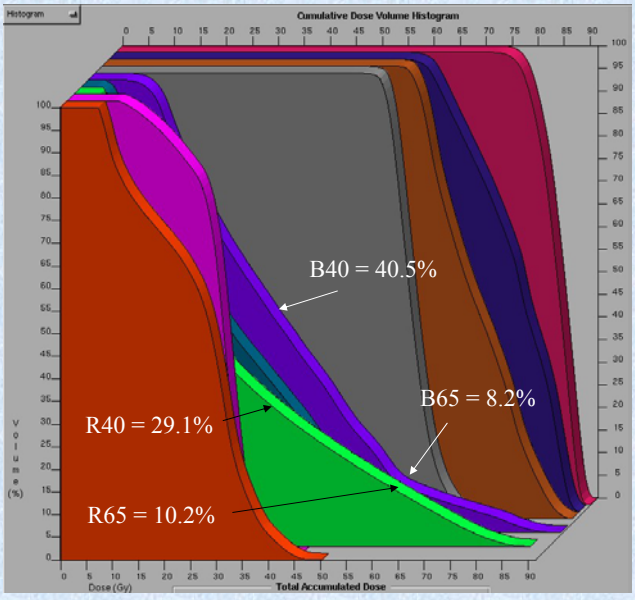
Lymphatic irradiation study

- 10 patient data sets
- Generate plans for each stage in targeting progression
- Evaluate effect of nodal irradiation on our routine prostate IMRT plan acceptance criteria
- Evaluate effect on bowel
- Evaluate effect on erectile tissues
- Treatment time (logistical concerns as well as patient comfort)
- Physics concerns (dose per fraction vs. “cone downs”, increased “hot spots”, PTV growth and localization technique, rectal expansion and inclusion of presacral nodes, etc.)

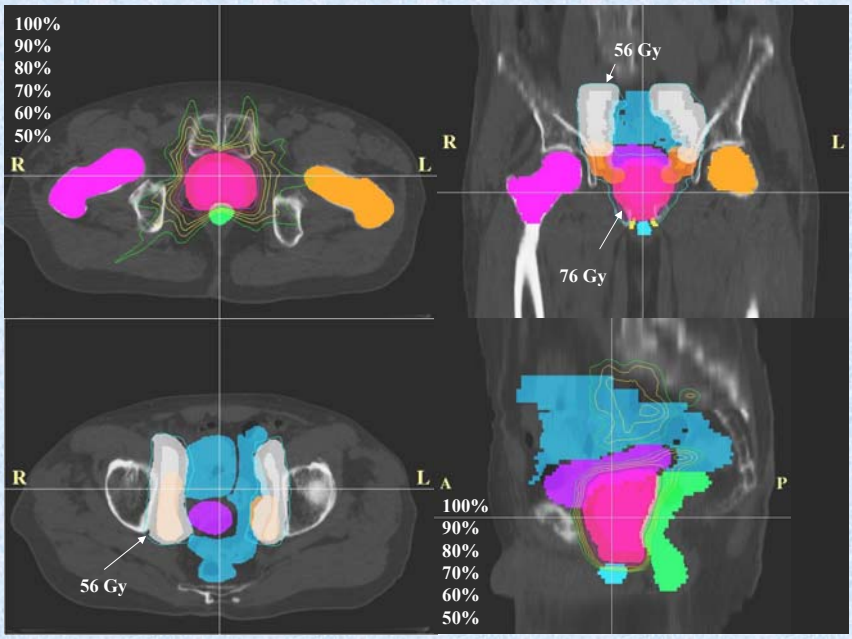
Extended Lymphatics (good)



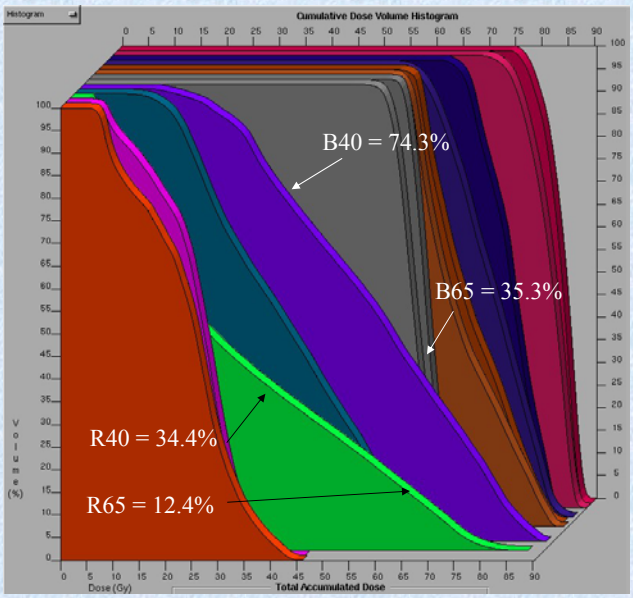
Extended Lymphatics (good)

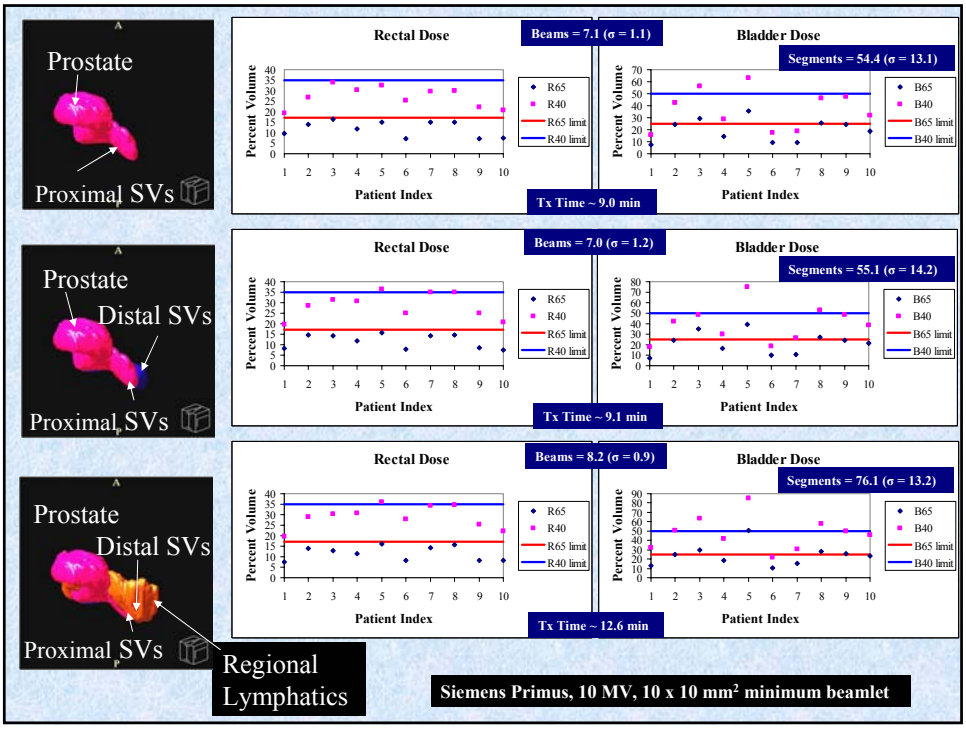


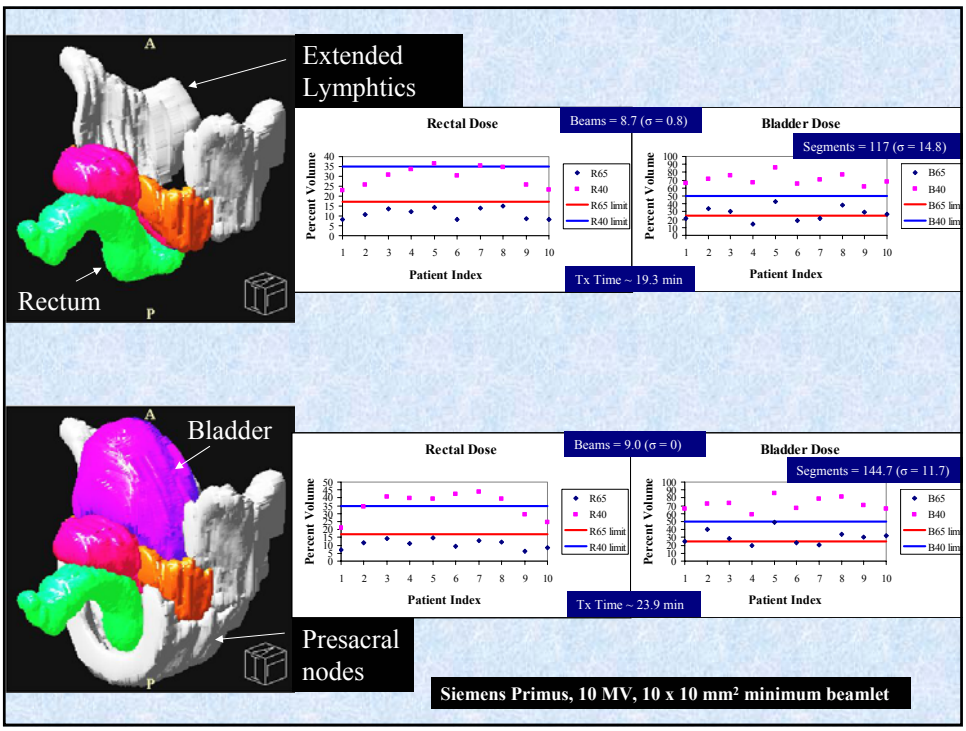
Extended Lymphatics (bad)



Extended Lymphatics (bad)




Prostate
Proximal SVs
Rectal Dose
Beams = 7.1 (σ = 1.1)
Bladder Dose
Segments = 54.4 (σ = 13.1)
Percent Volume
Patient Index
R65
R40
R65 limit
R40 limit
B65
B40
B65 limit
B40 limit
Tx Time ~ 9.0 min
Prostate
Distal SVs
Proximal SVs
Rectal Dose
Beams = 7.0 (σ = 1.2)
Bladder Dose
Segments = 55.1 (σ = 14.2)
Tx Time ~ 9.1 min
Prostate
Distal SVs
Proximal SVs
Regional Lymphatics
Rectal Dose
Beams = 8.2 (σ = 0.9)
Bladder Dose
Segments = 76.1 (σ = 13.2)
Tx Time ~ 12.6 min
Siemens Primus, 10 MV, 10 x 10 mm² minimum beamlet

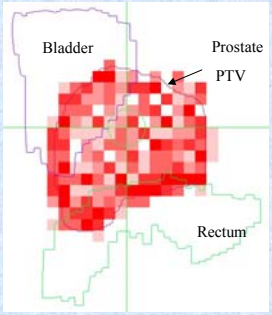

Extended Lymphtics
Rectum
Rectal Dose
Beams = 8.7 (σ = 0.8)
Bladder Dose
Segments = 117 (σ = 14.8)
Percent Volume
Patient Index
R65
R40
R65 limit
R40 limit
B65
B40
B65 limit
B40 limit
Tx Time ~ 19.3 min
Bladder
Presacral nodes
Rectal Dose
Beams = 9.0 (σ = 0)
Bladder Dose
Segments = 144.7 (σ = 11.7)
Tx Time ~ 23.9 min
Siemens Primus, 10 MV, 10 x 10 mm² minimum beamlet

Varian 21 Ex & Siemens Primus

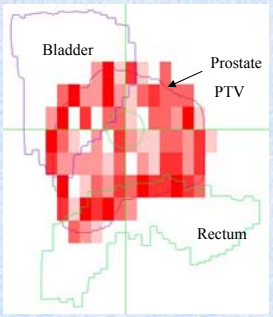
- 1 cm leaf width vs 5 mm leaf width
- 10 x 10 mm^2 minimum beamlet vs 5 x 5 mm^2
- We limit to 6-9 beam directions (primarily due to treatment time)
- Corvus treatment planning
- Increased MU → Increase leakage → secondary malignancies?, shielding concerns?

$$MSF_{mod} = MU_{IMRT}/MU_{3D\ CRT}$$

Price et al. JACMP 2003



5 x 5 mm^2 beamlets



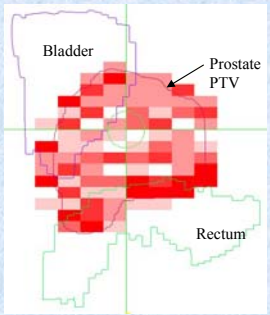
10 x 5 mm^2 beamlets

Collimator 0 degrees

10 x 5 mm^2 beamlets

Collimator **90 degrees.**

This places the short axis of the beamlet ~perpendicular to the prostate-rectal interface

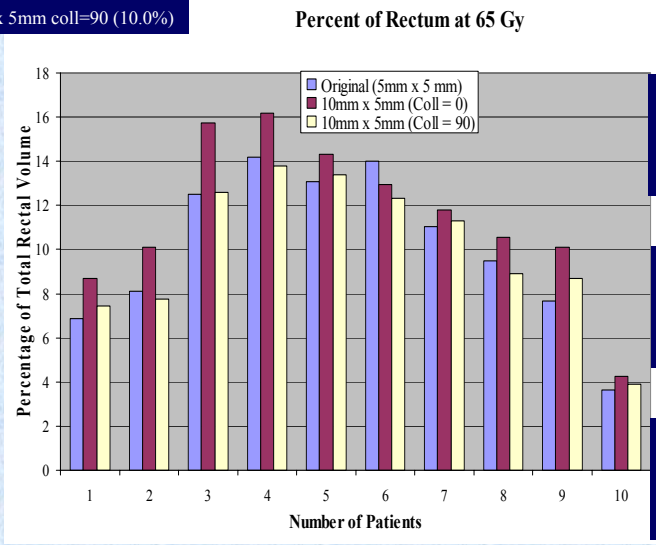


Mean values

5mm x 5mm (10.1%)

10mm x 5mm coll=0 (11.5%)

10mm x 5mm coll=90 (10.0%)



Comparisons

5mm x 5mm to 10mm x 5mm coll=0

p=0.004 (significant)

Comparisons

5mm x 5mm to 10mm x 5mm coll=90

p=0.85 (**NOT** significant)

Comparisons

10mm x 5mm coll=0 to 10mm x 5mm coll=90

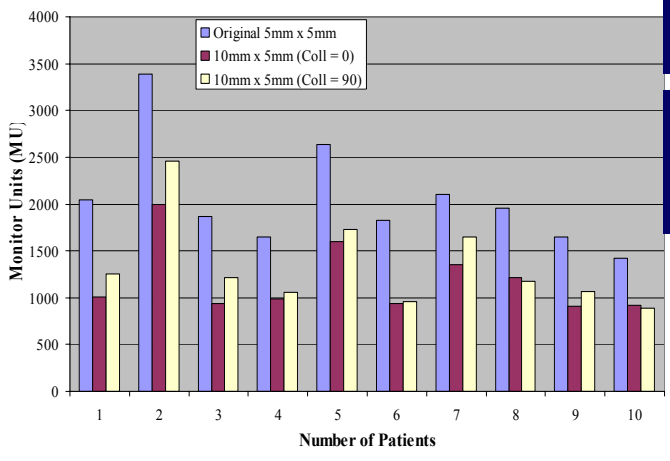
P<0.0001 (significant)

Mean values

5mm x 5mm (2055 MU)

10mm x 5mm coll=0 (1186 MU)

10mm x 5mm coll=90 (1344 MU)



Comparisons

5mm x 5mm to 10mm x 5mm coll=0

P<<0.001 (**HIGHLY** significant)

Comparisons

5mm x 5mm to 10mm x 5mm coll=90

P<<0.001 (**HIGHLY** significant)

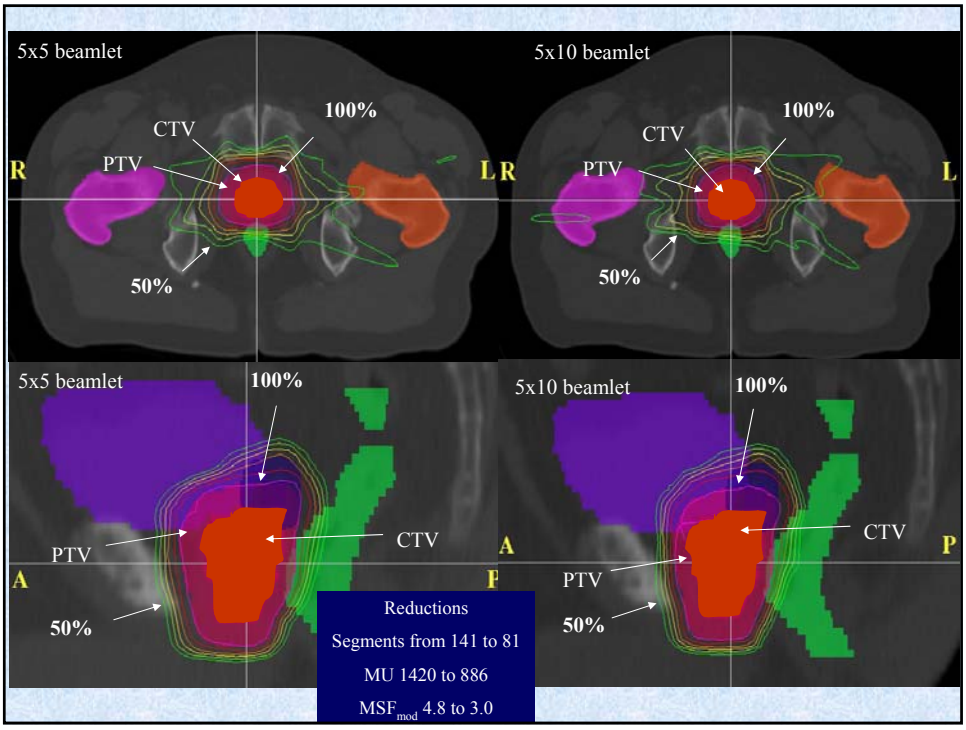
Analysis

5 mm x 5 mm beamlets

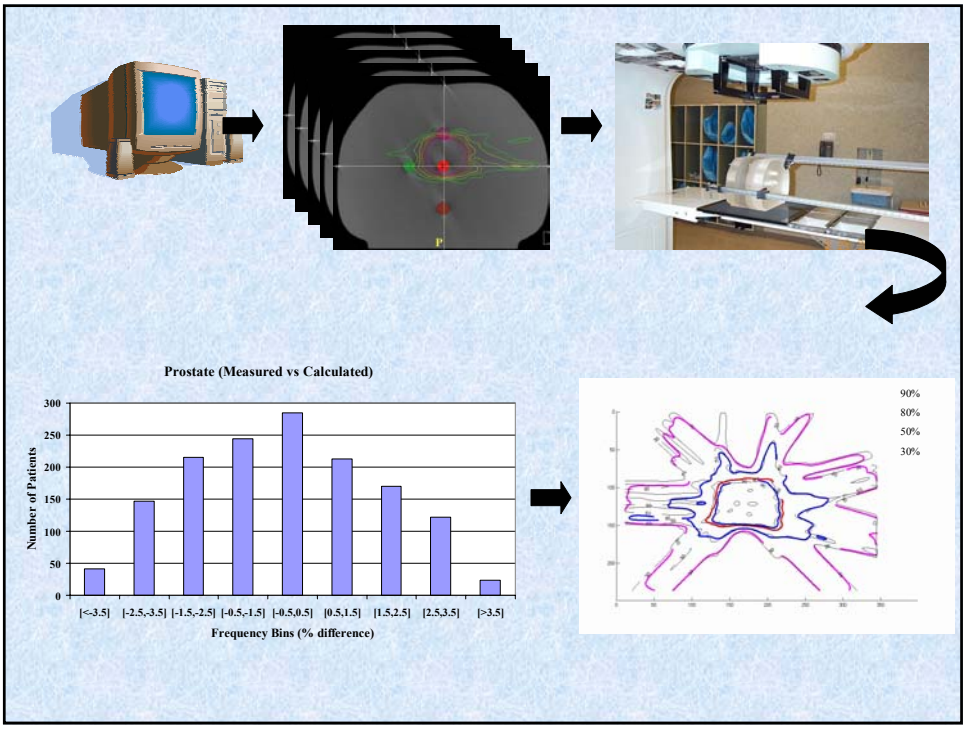
- Average # of segments ≈ 386
- Average # of MU ≈ 2055
- Average MSF_{mod} ≈ 7.0

10 mm x 5 mm beamlets (coll 90)

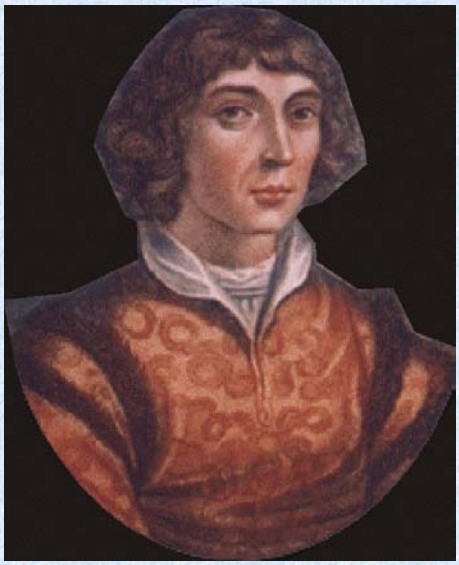
- Average # of segments ≈ 197 (~49 % reduction)
- Average # of MU ≈ 1344 (~34.6 % reduction)
- Average MSF_{mod} ≈ 4.6 (~34.3 % reduction)



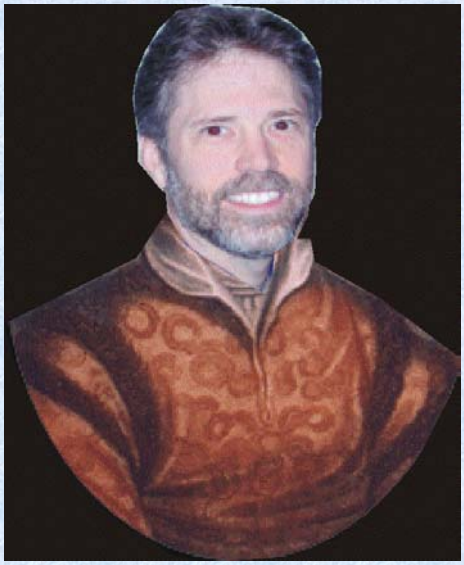
Routine QA


Prostate (Measured vs Calculated)
Number of Patients
300
250
200
150
100
50
0
|<-3.5|
|-2.5,-3.5|
|-1.5,-2.5|
|-0.5,-1.5|
|-0.5,0.5|
|0.5,1.5|
|1.5,2.5|
|2.5,3.5|
|>3.5|
Frequency Bins (% difference)
90%
80%
50%
30%

HooRay!!! Post Docs!!!



Copernicus



Pollack-nicus