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.

- Retrograde urethograms are not performed.

Imaging modality may affect treatment regime
Imaging artifacts may affect contouring

PTV growth = 8mm in all directions except posteriorly where a 5mm margin is typically used.

The “effective margin” is defined by the distance between the posterior aspect of the CTV and the prescription isodose line and typically falls between 3 and 8 mm.
Acceptance Criteria

**DVH Acceptance Criteria**

- $\text{PTV}_{95\%} \geq 100\% \text{ Rx}$
- $R_{65\text{ Gy}} \leq 17\% \text{ V}$
- $R_{40\text{ Gy}} \leq 35\% \text{ V}$
- $B_{65\text{ Gy}} \leq 25\% \text{ V}$
- $B_{40\text{ Gy}} \leq 50\% \text{ V}$
- $\text{FH}_{50\text{ Gy}} \leq 10\% \text{ V}$

Good DVH

$\text{PTV}_{95} = 100\%$

$R_{40} = 22.7\%$

$R_{65} = 8.3\%$

$B_{65} = 8.4\%$

$R_{40} = 19\%$

$B_{40} = 8.4\%$
Good plan example (axial)

The 50% isodose line should fall within the rectal contour on any individual CT slice.

The 90% isodose line should not exceed ¼ the diameter of the rectal contour on any slice.

“Effective margin”

Good plan example (sagital)

Attempting to get isodose line “compression” (fast dose fall-off) at the prostate-rectum interface.
DVH Acceptance Criteria

PTV_{95\%} \geq 100\% \text{ Rx}
R_{65 \text{ Gy}} \leq 17\% V
R_{40 \text{ Gy}} \leq 35\% V
B_{65 \text{ Gy}} \leq 25\% V
B_{40 \text{ Gy}} \leq 50\% V
FH_{50 \text{ Gy}} \leq 10\% V

Bad plan example (axial)

The 50\% isodose line falls outside the rectal contour
**Bad plan example (sagital)**

The 50% isodose line falls outside the rectal contour

**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 $\alpha/\beta$ ratio
  of 1.5.
- Distal sv, lymphatics
  (50 Gy @ ~1.5 Gy/fx)
- 26 fractions total

BED for rectum & bladder

- $R_{50 \text{ Gy}} \leq 17\%V$
- $R_{31 \text{ Gy}} \leq 35\%V$
- $B_{50 \text{ Gy}} \leq 25\%V$
- $B_{31 \text{ Gy}} \leq 50\%V$
- $FH_{40 \text{ Gy}} \leq 10\%V$

Number of Beam Directions

In the interest of delivery time we typically begin with 6 and progress to $\leq 9$

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
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.

Prostate Bed

Note lack of physical structures for alignment with BAT

Paskalev et al. (In Press)
Regions for dose constraint

<table>
<thead>
<tr>
<th>Region</th>
<th>Limit</th>
<th>% volume limit</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
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<tr>
<td>1</td>
<td>90% of target goal</td>
<td>20</td>
<td>45% of target goal</td>
<td>Target Max</td>
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<td>20</td>
<td>40%</td>
<td>90% of target goal</td>
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<tr>
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<td>75%</td>
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<td>5</td>
<td>30%</td>
<td>1</td>
<td>15%</td>
<td>35%</td>
</tr>
<tr>
<td>6</td>
<td>20%</td>
<td>1</td>
<td>10%</td>
<td>25%</td>
</tr>
</tbody>
</table>

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
Nodal Irradiation

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

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


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
Prostate

Proximal SVs

Distal SVs
Prostate
Proximal SVs
Distal SVs
Regional Lymphatics
Extended Lymphatics
Rectum

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.)
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?

$$\text{MSF}_{\text{mod}} = \frac{\text{MU}_{\text{IMRT}}}{\text{MU}_{\text{3D CRT}}}$$

Price et al. JACMP 2003
Percent of Rectum at 65 Gy

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)

Comparison of Daily Monitor Units

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\text{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\text{mod} ≈ 4.6 (~34.3 % reduction)

Reductions
Segments from 141 to 81
MU 1420 to 886
MSF\text{mod} 4.8 to 3.0
Routine QA

Prostate (Measured vs Calculated)

Number of Patients

Frequency Bins (% difference)

[Graph showing frequency distribution of prostate measurements]
HooRay!!! Post Docs!!!

Weijun (Wil) Xiong
Wei Luo
Jiajin (James) Fan
Xiu Xu
Sotirios Stathakis

Zuoqun (Jay) Chen
Freek DuPlessis
Antonio Leal Plaza
Jennifer Zhu

Copernicus

Pollack-nicus