NYU Langone Health

CHALLENGES IN PROSTATE SBRT TREATMENT PLANNING

Matthew Witten, PhD, DABR
Chief Physicist, Department of Radiation Oncology
Director, Division of CyberKnife Radiosurgery
Clinical Associate Professor, NYU Grossman Long Island School of Medicine

Radiation Oncology

Disclosures

- None

The Cognitive Style of PowerPoint
Edward Tufte (2003)

“PP convenience for the speaker can be costly to both content and audience. These costs result from the cognitive style characteristic of the standard default PP presentation: foreshortening of evidence and thought, low spatial resolution, a deeply hierarchical single-path structure as the model for organizing every type of content, breaking up narrative and data into slides and minimal fragments, rapid temporal sequencing of thin information rather than focused spatial analysis, conspicuous decoration and Phluff, a preoccupation with format not content, an attitude of commercialism that turns everything into a sales pitch.”

Optimization

Quasi-Newton Methods

- Many treatment planning systems use some flavor of limited-memory quasi-Newton optimization.

$$\nabla f(x_0 + \Delta x) = 0 \qquad \Delta x_0 = -B^{-1} \cdot \nabla f(x_0)$$

- Approximates the inverse of the Hessian sparsely and implicitly.
- Does not admit hard constraints.
- Weighted optimization with a quadratic penalty function.
- Segment-weight optimization subsequent to fluence optimization.
- Generally very fast optimization times.

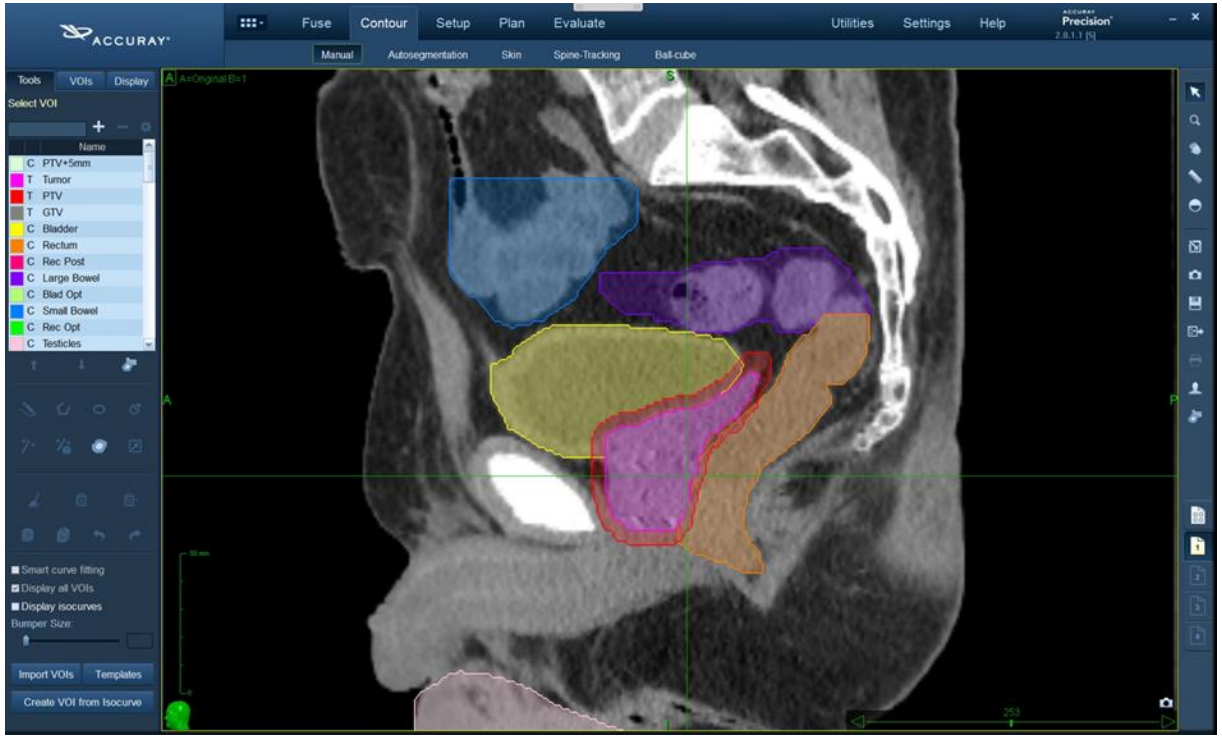
Optimization

- Optimization usually on a single weighted objective function with a simple quadratic penalty.
  - MCO is an alternative.
  - Knowledge-based planning (neural nets) gaining popularity.
- Overlap between PTV and OARs drives optimization.
  - Sample overlap regions (OAR ∩ PTV) densely.
  - Sample rest of OAR more sparsely (OAR\(OAR ∩ PTV)).
  - Makes evaluation of the objective function value faster, which speeds up the optimization.
  - Create optimization structures for overlap regions with a 2 mm margin on PTV and OAR.

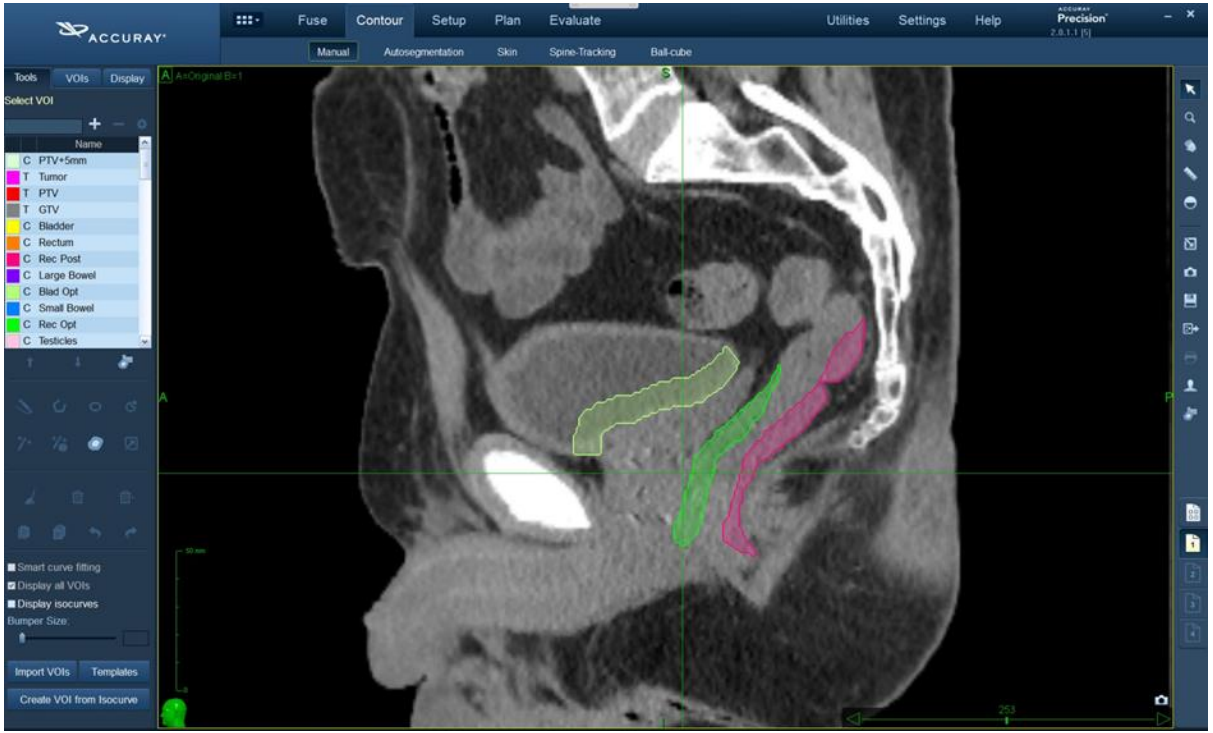
Points to Remember

- Optimization is a purely mathematical process.
  - The optimizer does not “know” anything about the clinical problem.
  - Any expert knowledge must be provided by the treatment planner.
- Solution space is highly degenerate.
  - Generally most local minima are good, clinically-acceptable solutions.
- Sampled points are surrogates for OARs, targets, and tuning structures; pay close attention to their density and distribution.
  - 50 to 100 points/cm^3 (Spirou and Chui, 1998).
- It is not necessary to add a term to the objective function for every goal in the physician’s intent.
- 200k-400k optimization points total for most GPU-based calculations.

Contoured Structures



Optimization Structures



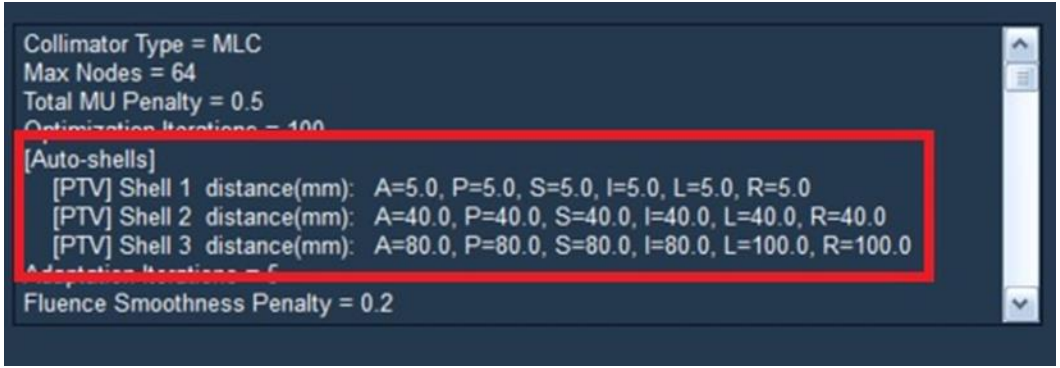
Prostate Treatment Planning Goals

Prostate CK SBRT PRF, w MLC planning

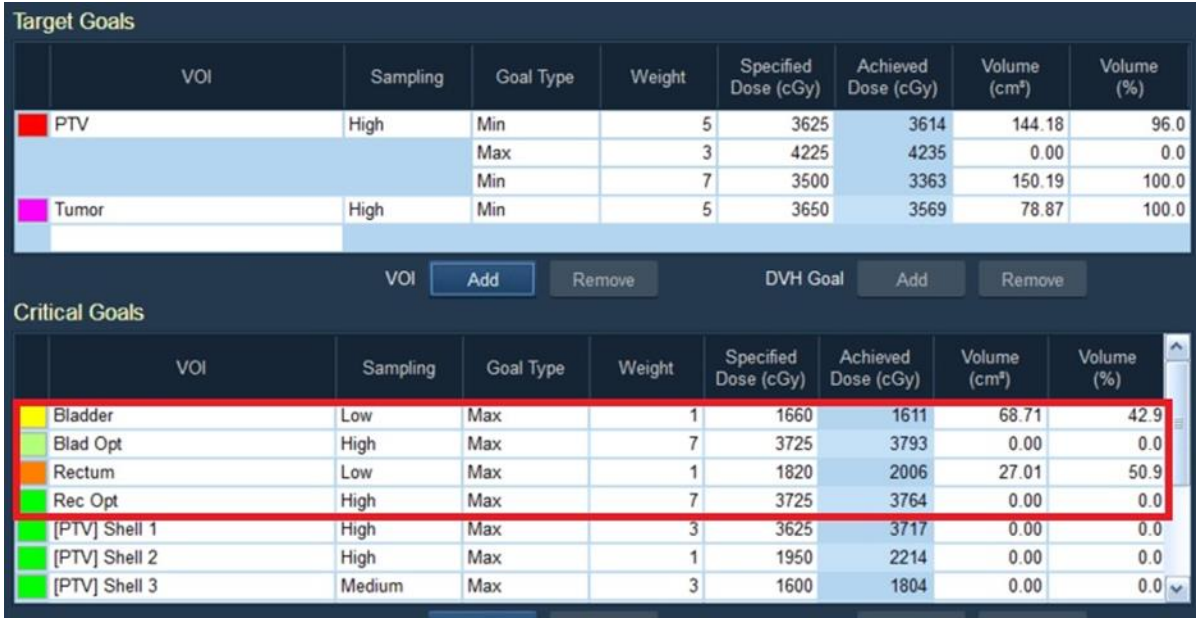
Fusion order: please fuse CT sim with MRI prostate; fusion to fiducial markers, with attention to the posterior prostate/anterior rectum interface for optimized contour/planning.

Structure	Dose Limit	Mandatory	Guideline
Rx: 725cGy x 5		☒	☐
PTV Margins:		Anisotropic, 3mm posteriorly, 5mm elsewhere	
D95 ≥ 36.25Gy		☒	☐
D0 ≤ 42.2Gy		☒	☐
Dmin ≥ 30Gy		☒	☐
Max dose NOT inside bladder or rectum/bowel		☒	☐
Rectum	$V_{37.8Gy}$ < 5 %	☒	☐
	$V_{33.9Gy}$ < 20 %	☒	☐
	V_{29Gy} < 40 %	☒	☐
*Source ASTRO 2015	*$V_{22.8Gy}$ < 50 %	☒	☐
	$V_{18.2Gy}$ < 60 %	☒	☐
	Max<38Gy	☐	☒
	Max<39Gy	☒	☐
Bladder	$V_{37.8Gy}$ < 5 %	☒	☐
*Georgetown	V_{37Gy} < 5cc's	☒	☐
	$V_{16.6Gy}$ < 50 %	☒	☐
	Max<38Gy	☐	☒
	Max<39Gy	☒	☐
Large bowel-anatomic	$V_{23.7Gy}$ < 20cc's	☒	☐
	Max< 37Gy	☒	☐
Small bowel-anatomic	Max< 32Gy	☒	☐
	$V_{14.2Gy}$ < 5cc's	☒	☐
Testicles/ Scrotum	Max <1.9Gy	☐	☒
Aim to minimize beams through testicles/scrotum			
Additional Instructions		UrethraDmax<41.8Gy Urethra D1cc<39.5Gy Urethra Dmin>36Gy	

Shells


Collimator Type = MLC
Max Nodes = 64
Total MU Penalty = 0.5
[Auto-shells]
[PTV] Shell 1 distance(mm): A=5.0, P=5.0, S=5.0, I=5.0, L=5.0, R=5.0
[PTV] Shell 2 distance(mm): A=40.0, P=40.0, S=40.0, I=40.0, L=40.0, R=40.0
[PTV] Shell 3 distance(mm): A=80.0, P=80.0, S=80.0, I=80.0, L=100.0, R=100.0
Fluence Smoothness Penalty = 0.2

D-V Objectives 1



Target Goals

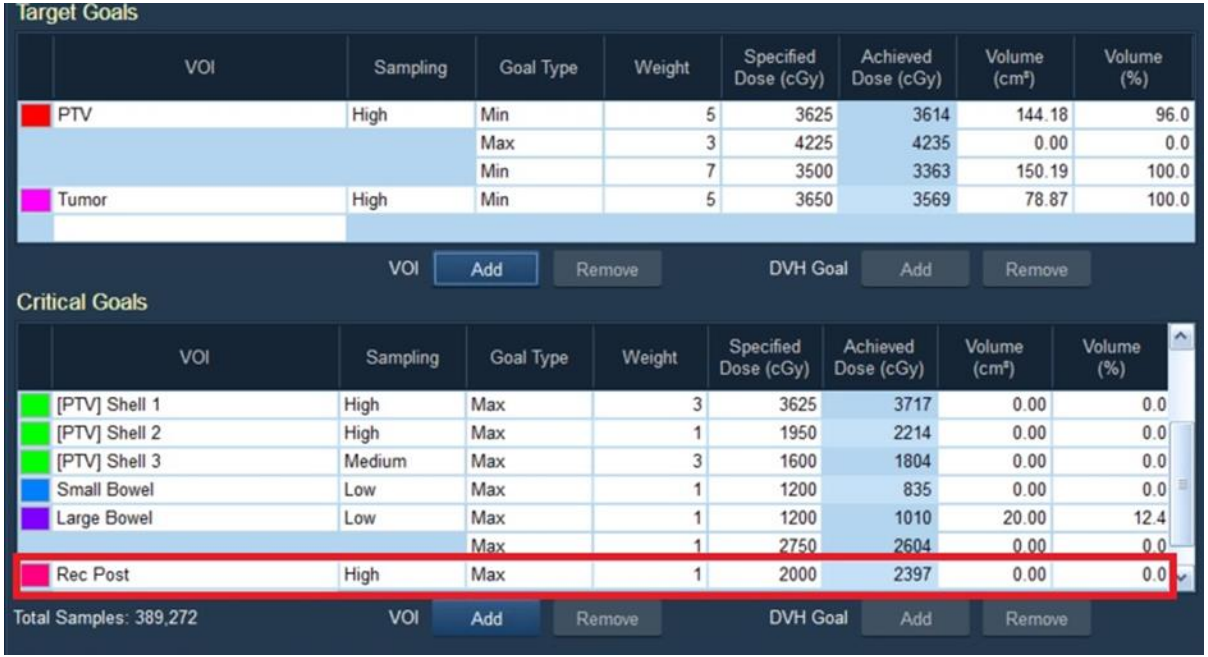
VOI	Sampling	Goal Type	Weight	Specified Dose (cGy)	Achieved Dose (cGy)	Volume (cm³)	Volume (%)
PTV	High	Min	5	3625	3614	144.18	96.0
		Max	3	4225	4235	0.00	0.0
		Min	7	3500	3363	150.19	100.0
Tumor	High	Min	5	3650	3569	78.87	100.0

VOI Add Remove DVH Goal Add Remove

Critical Goals

VOI	Sampling	Goal Type	Weight	Specified Dose (cGy)	Achieved Dose (cGy)	Volume (cm³)	Volume (%)
Bladder	Low	Max	1	1660	1611	68.71	42.9
Blad Opt	High	Max	7	3725	3793	0.00	0.0
Rectum	Low	Max	1	1820	2006	27.01	50.9
Rec Opt	High	Max	7	3725	3764	0.00	0.0
[PTV] Shell 1	High	Max	3	3625	3717	0.00	0.0
[PTV] Shell 2	High	Max	1	1950	2214	0.00	0.0
[PTV] Shell 3	Medium	Max	3	1600	1804	0.00	0.0

D-V Objectives 2



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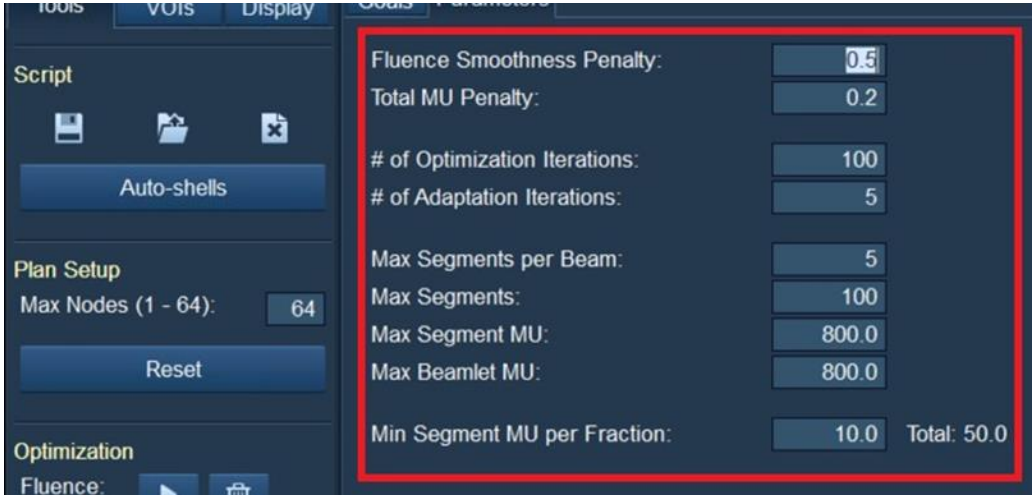
[PTV] Shell 2	High	Max	1	1950	2214	0.00	0.0
[PTV] Shell 3	Medium	Max	3	1600	1804	0.00	0.0
Small Bowel	Low	Max	1	1200	835	0.00	0.0
Large Bowel	Low	Max	1	1200	1010	20.00	12.4
		Max	1	2750	2604	0.00	0.0
Rec Post	High	Max	1	2000	2397	0.00	0.0

Total Samples: 389,272 VOI Add Remove DVH Goal Add Remove

Optimization Parameters



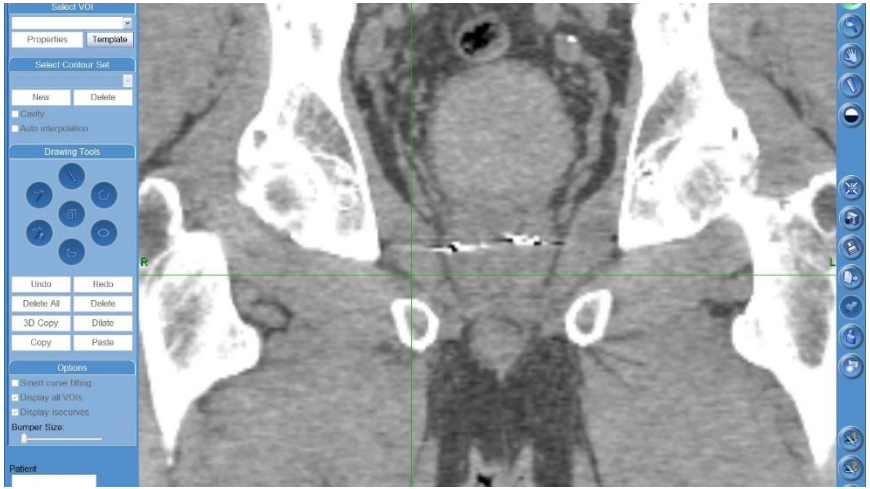
Dose Distribution

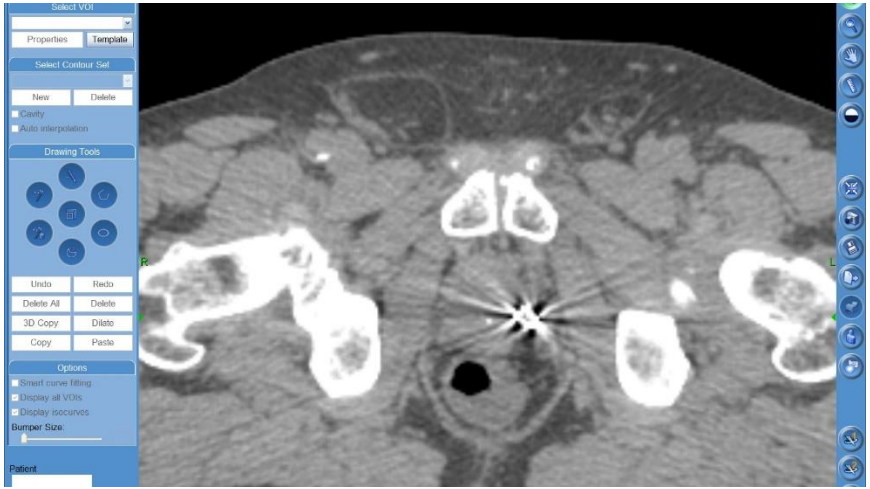
Fiducial Placement

Fiducials

- Surrogate for the prostate.
- Tracking in six dof.
  - If used for tracking, fiducial configuration (spacing) is important. Without proper placement, tracking of rotations may not be possible, which has implications for PTV margins.

Fiducials Placed Transrectally Can Be Problematic For 6DOF Tracking





CT

- No more than 1.25 mm slice thickness.
  - Produces DRRs with acceptable resolution for setup.
  - Sufficient for fiducial tracking.

Prostatic Urethral Dose

Optimizing Prostatic Urethral Dose

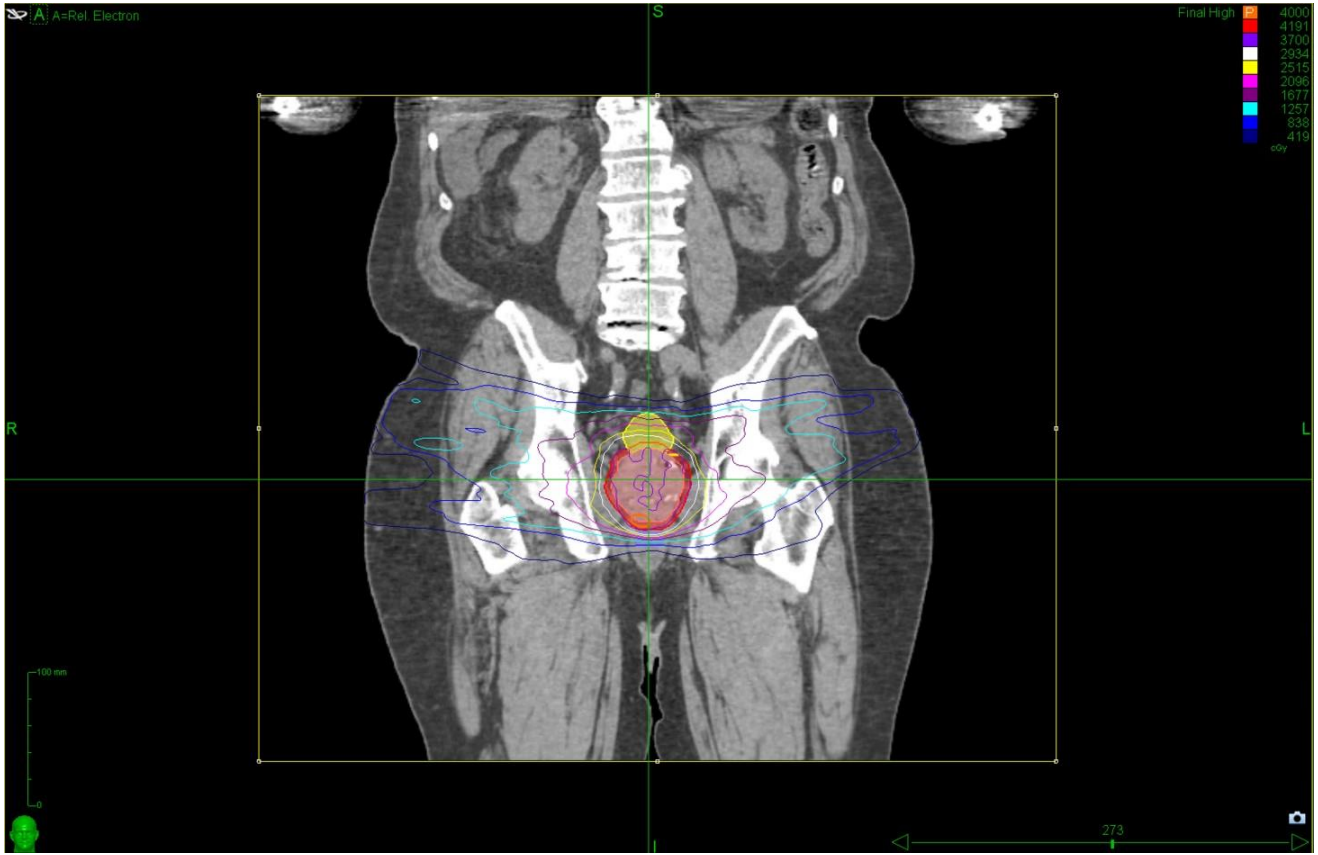
- In patients with localized prostate cancer, US-SBRT techniques limiting maximum doses to urethra below a 90-GyEQD2 ($\alpha/\beta = 3$ Gy) threshold represent a promising strategy to mitigate acute and long-term grade ≥ 2 GU toxicity, while maintaining at the same time acceptable rates of local disease control.*
  - Grade 2 GU toxicity 12.1% - 14%.*
- Dose-reduction to urethra below 70 GyEQD2 ($\alpha/\beta = 3$ Gy) may enable a further reduction in long-term GU toxicity in selected patients with no tumor in the transition zone.*
  - Grade 2 GU toxicity < 8% @ 5 years.*

*Source: Le Guevelou J, Bosetti DG, Castronovo F, Angrisani A, de Crevoisier R, Zilli T. State of the art and future challenges of urethra-sparing stereotactic body radiotherapy for prostate cancer: a systematic review of literature. World J Urol. 2023 Nov;41(11):3287-3299. doi: 10.1007/s00345-023-04579-6. Epub 2023 Sep 5. PMID: 37668718; PMCID: PMC10632210.

5 Fx Prostatic Urethral D-V Objectives

- Dmax < 42 Gy.
- D1cc < 40 Gy.
- Dmin > 36 Gy.
  - Needed to avoid a cold spot in the prostate.

Urethral Sparing



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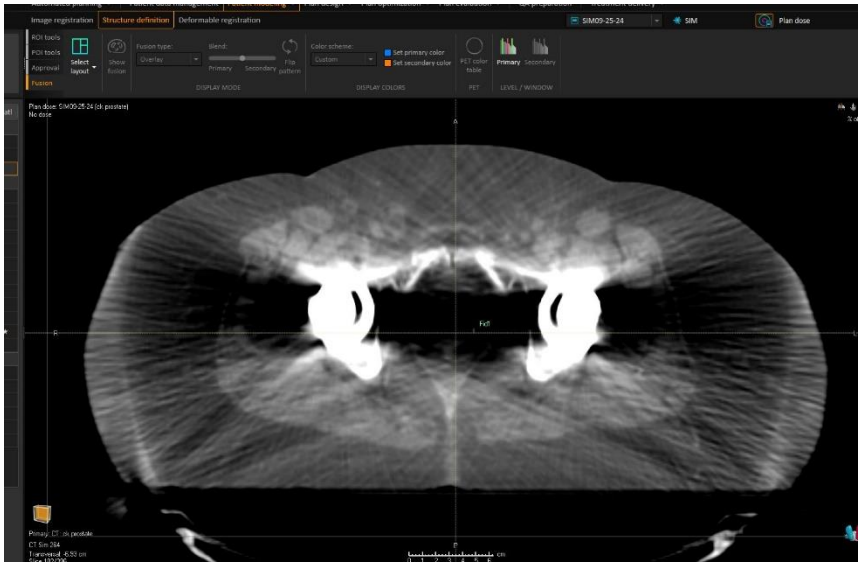
Hip Replacements

Bilateral Hip Replacements - CT



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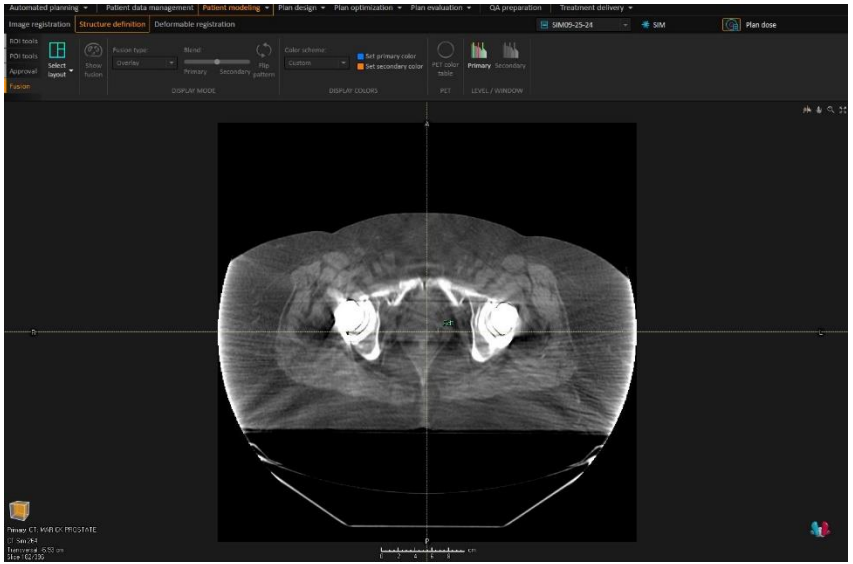
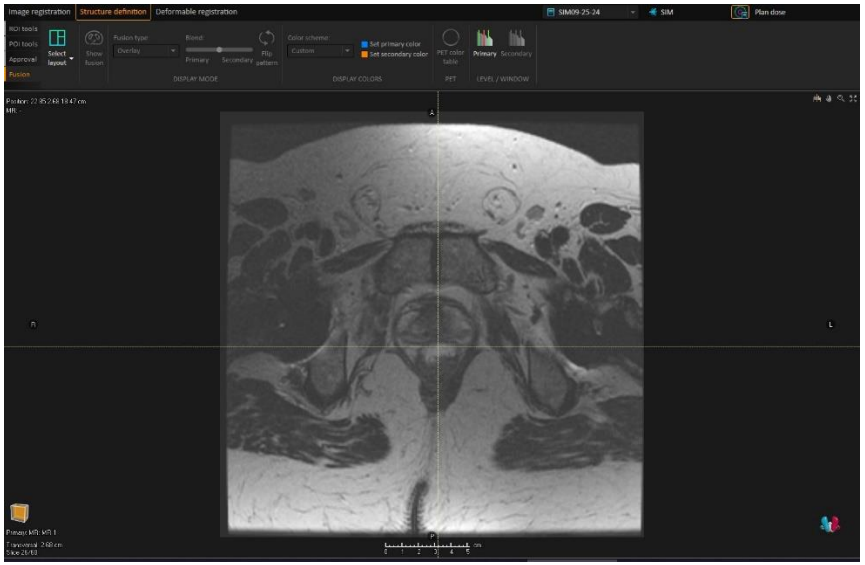
Bilateral Hip Replacements – MAR CT



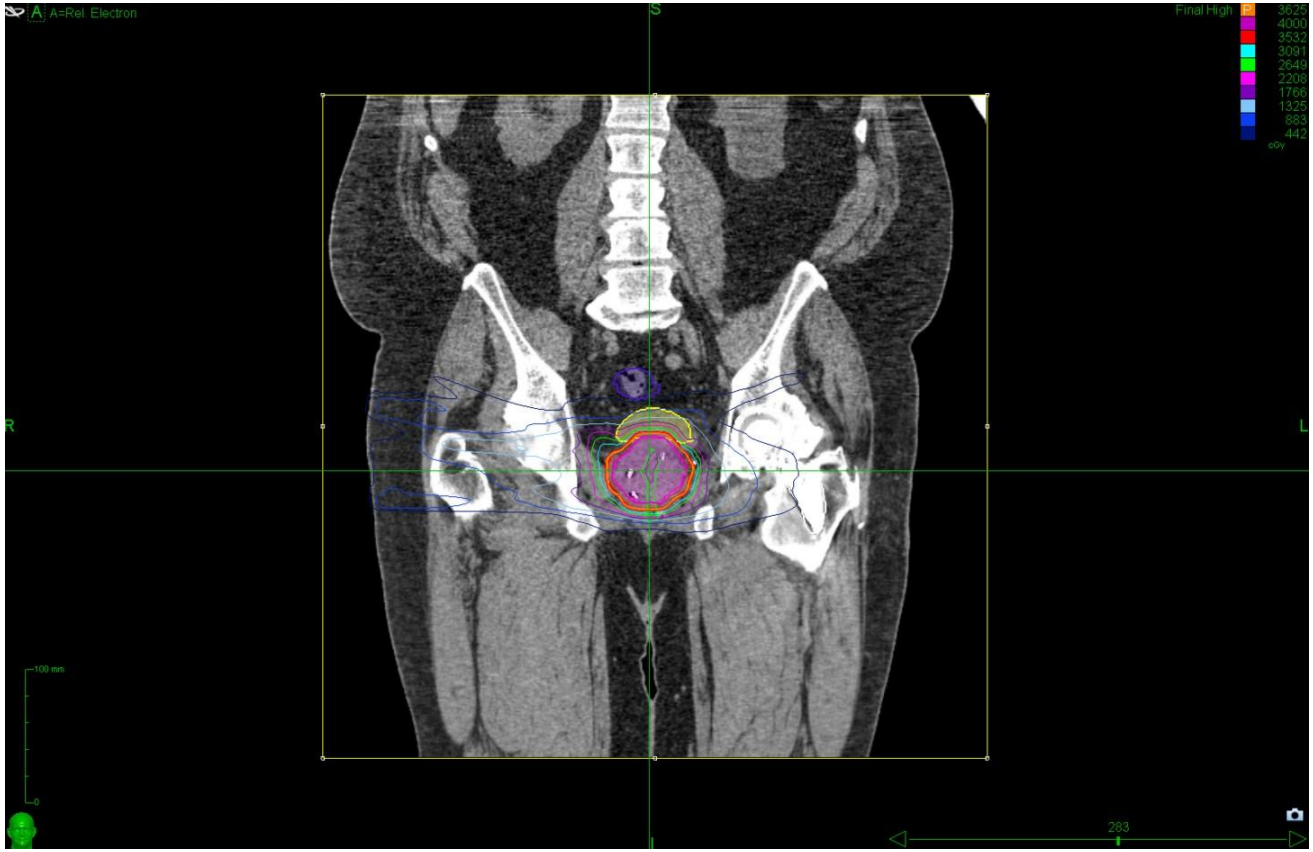
Bilateral Hip Replacements - MRI



Planning Considerations

- Use a MAR scan for planning.
- Contour the implants.
- Make implant ROIs exit only.
  - May require a larger node set than prostate path.
    - Decreased pitch tolerance may lead to difficulties in tx delivery.

Pt With Left Hip Implant



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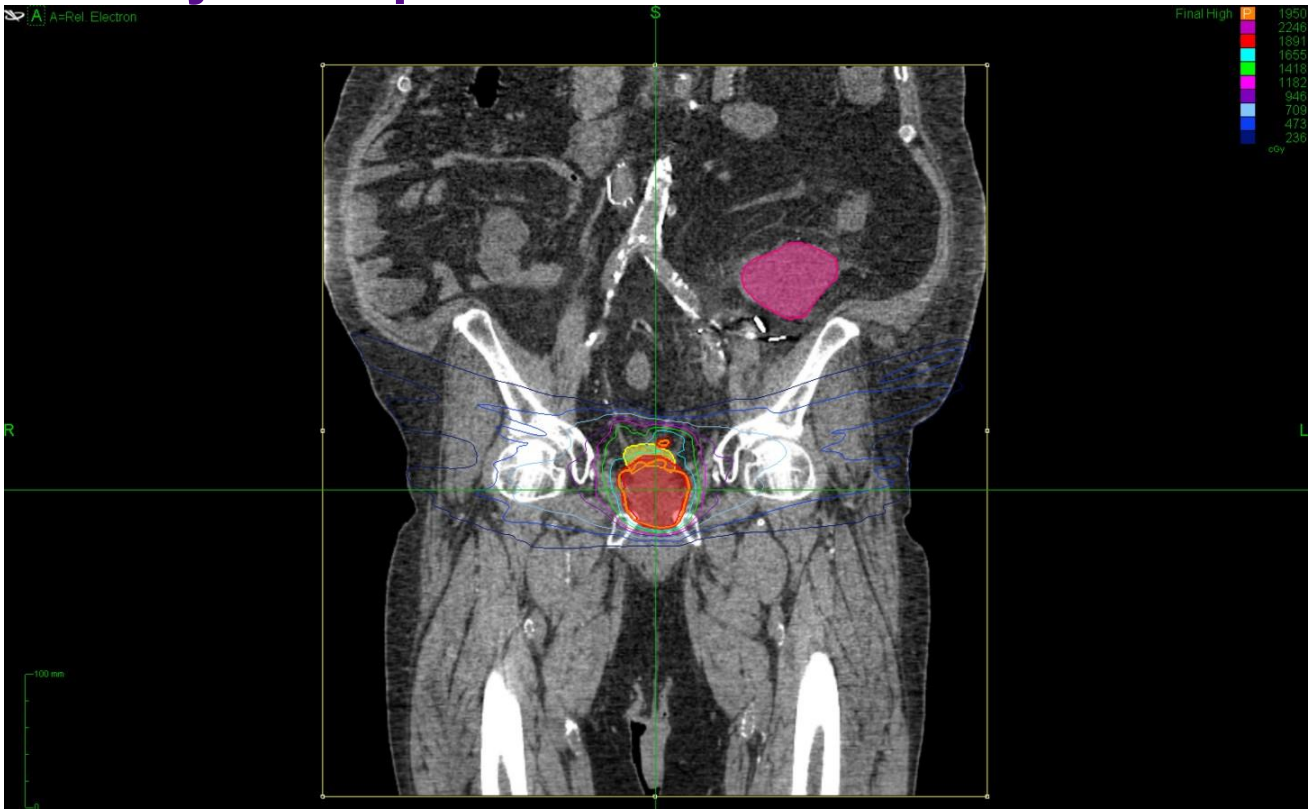
Kidney Transplant

Pt With Kidney Transplant

- GS 4+4.
- ADT + pelvic EBRT (45 Gy) + CK SBRT boost (6.5 Gy x 3).
- D-V objectives for transplanted kidney.
  - Mean dose ≤ 3.9 Gy EQD2.
    - Planned mean dose = 2.28 Gy EQD2.
  - Dmax ≤ 10 Gy EQD2.
    - Planned Dmax = 8.99 Gy EQD2.
  - No beam intersections with transplanted kidney allowed.

Pt With Kidney Transplant



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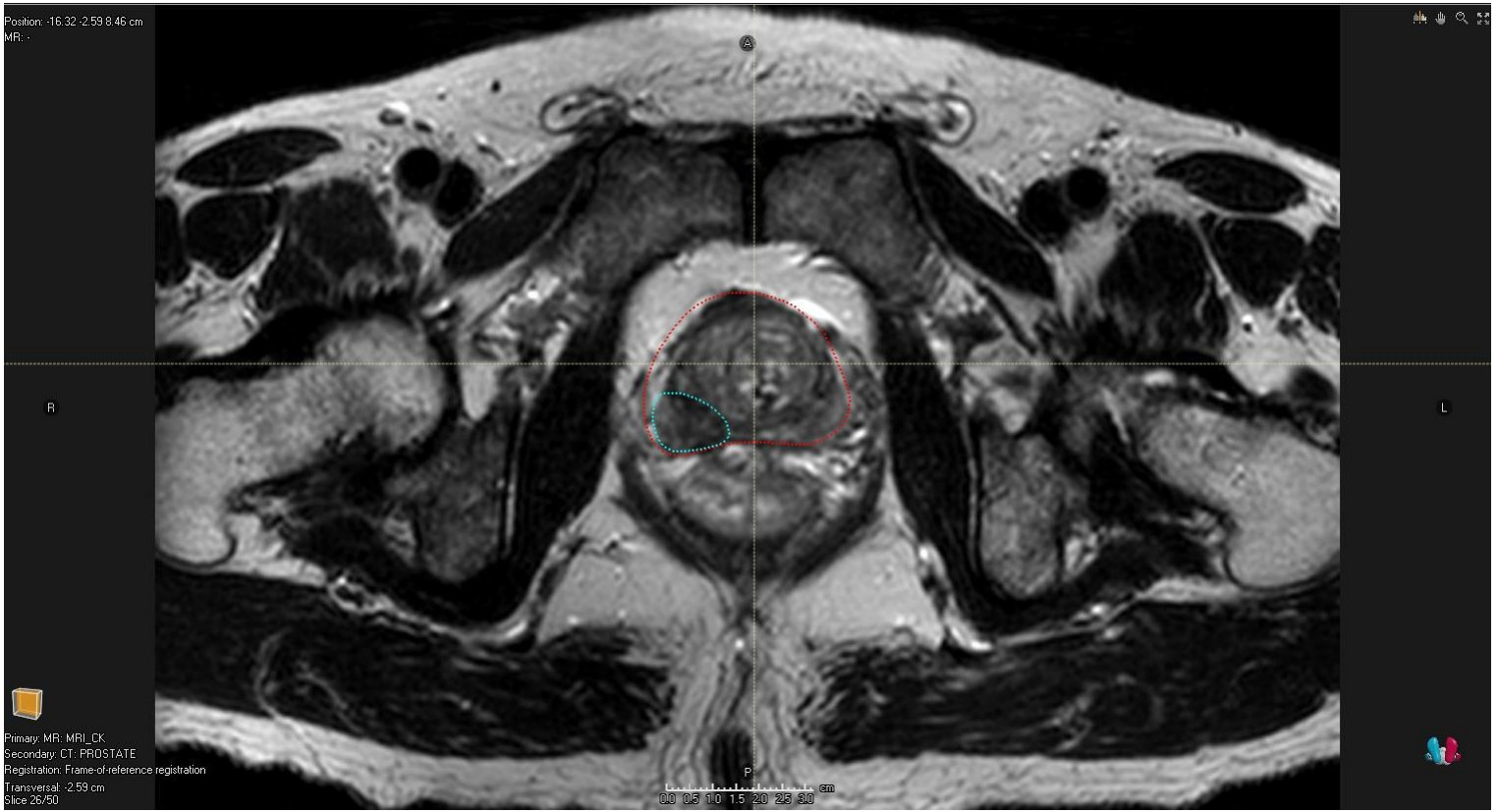
Focal Boost To Intraprostatic Lesions

Identifying DILs For Boost

- FLAME trial 10 yr results*
  - The 10-year bDFS was 71% (95% CI, 65% to 77%) in the standard arm versus 86% (95% CI, 81% to 91%) in the focal boost arm with a statistically significant difference between trial arms (P < .001).
  - The addition of a focal boost reduced the number of biochemical failures by more than half (adjusted hazard ratio [HR], 0.40 [95% CI, 0.26 to 0.61]; P < .001).
  - The 10-year results for DFS were 67% (95% CI, 61% to 73%) in the standard arm versus 81% (95% CI, 76% to 87%) in the focal boost arm (HR, 0.48 [95% CI, 0.33 to 0.69]; P < .001).
- DWI + T2 ideal for visualization of intraprostatic lesions for boost.

*Source: Karolína Menne Guricová et al. Focal Boost to the Intraprostatic Tumor in External Beam Radiotherapy for Patients With Localized Prostate Cancer: 10-Year Outcomes of the FLAME Trial. J Clin Oncol 43, 3065-3069(2025). DOI:10.1200/JCO-25-00274

MRI-Delineated SIB Volume



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Thank you

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