# Efficient outcomes-driven treatment planning using the Pinnacle system

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## Thanks to

- Beth Pierburg, CMD
- Kevin Moore, PhD
- Rojano Kashani, PhD
- Jan Wilkins, PhD
- Aditya Apte, PhD
- Vanessa Clark, PhD
- Jeff Michalski, MD
- Funding from the NIH, Varian, and Tomotherapy.

## Outline

1. What are we trying to do?
2. What do we want to do: Prioritized prescription optimization (Clark et al.)
3. Tools at your disposal in Pinnacle
4. Constrained optimization in Pinnacle
5. Overlap-guided planning automation (Moore et al.)
6. Where are we now?

## What are we trying to do?

- Achieve a high dose to the target
- Achieve low dose to the normal tissues
- But this is impossible!

## So we…

- Make tradeoffs.
- But what are the treatment (physician) priorities?
- Usually there is a natural order:
  - Effective target coverage
  - Reduced dose to nearby critical normal structures
  - Minimal hotspots inside and outside target
  - Smoothed beam weights/low MUs

## Potential answer: Priopt

- Prioritized prescription optimization
- Successively optimize easy-to-solve problems in order of clinical priority
- Advantages
  - Clear tradeoffs
  - Characterizable solution
  - Can be optimal
  - Automation potential
  - Competitive with clinical results (this work)

(slides courtesy Vanessa Clark; see Clark et al, iCCR 2010)

## Prioritized prescription optimization: A comparison with current Pinnacle planning results

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Partially supported by NIH grant
R01 CA85181 and a grant from
TomoTherapy, Inc.

Prioritized prescription optimization

| | objectives | hard constraints |
|---|---|---|
| step I | 1st priority objective | 1st priority constraints |

# Objectives
## (based on physician preferences)

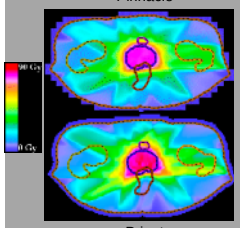
- Optimized in the following order:
  1. Maximize PTV D98 (Maximum PTV dose ≤ 75.6 Gy * 1.10)
  2. Minimize Rectum V65 & V40 (<17%, 35%)
  3. Minimize Bladder V65 & V40 (<25%, 50%)
  4. Minimize Normal Tissues mean & max dose
  5. Smoothing and minimize PTV mean dose

- Used mean-tail-dose instead of dose-volume objectives
  – Clark LAA 2008
  – Clark ICCR 2007

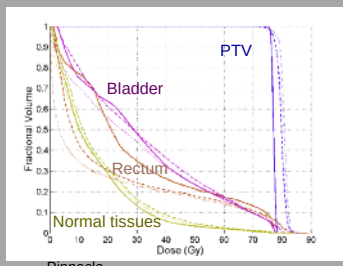


# Priopt vs. Pinnacle for one case

Pinnacle



Priopt



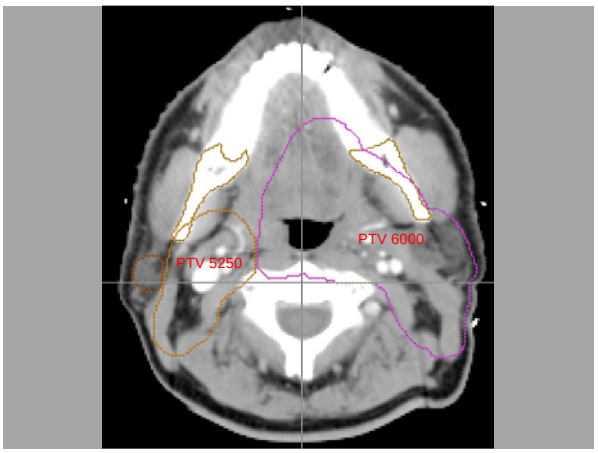

--- Pinnacle
… Priopt QIB
- - Priopt DPM final

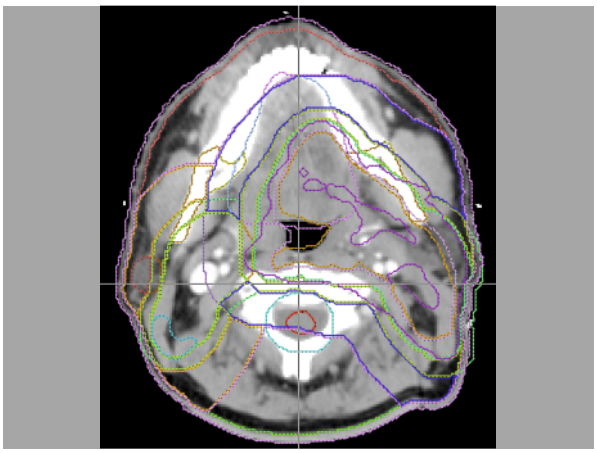


# Prioritized planning within Pinnacle

# Pinnacle has…

- Typical DVH constraints
- gEUD objectives
- Constrained optimization



## Required planning objectives [1/3]

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| LTPAROT_OPT | Max EUD | | 1950 | | | 1 | -- | 1 |
| RTPAROT_OPT | Max EUD | | 1400 | | | 1 | -- | 1 |
| POST AVOID | Max Dose | | 4000 | | | 1 | -- | |
| ZCM OUT_60 | Max EUD | | 3200 | | | 2 | -- | 1 |
| [illegible] | Max EUD | | 2700 | | | 1 | -- | 1 |
| MAND_OPT | Max EUD | | 2750 | | | 1 | -- | 1 |
| ORALCAV_OPT | Max EUD | | 3850 | | | 1 | -- | 1 |
| ZCM OUT_60 | Max Dose | | 5800 | | | 4 | -- | |
| [illegible] | Max Dose | | 4600 | | | 2 | -- | |

## Required planning objectives [2/3]

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight |
|---|---|---|---|---|---|---|
| PTV60_OPT | Max Dose | | 6150 | | | 41 |
| PTV60_OPT | Min Dose | | 6150 | | | 25 |
| INNER RING 60 | Min Dose | | 6150 | | | 65 |
| 5MM OUT RING | Max Dose | | 6000 | | | 1 |
| PTVS250_OPT | Min Dose | | 5400 | | | 10 |
| PTVS250_OPT | Max Dose | | 5600 | | | 33 |
| 5MM OUT RING | Max Dose | | 5250 | | | 5 |
| SHOULDER AVO | Max Dose | | 1900 | | | 1 |
| CORD + MARGIN | Max Dose | | 4150 | | | 35 |

## Required planning objectives [3/3]

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| OUTER BODY RIM | Max Dose | | 4500 | | | 2 | -- | |
| OUTER BODY RIM | Max EUD | | 800 | | | 2 | -- | 1 |
| PAROTID_OPT | Max EUD | | 4200 | | | 1 | -- | 1 |
| CORD_OPT | Max EUD | | 2000 | | | 1 | -- | 1 |
| 5MM OUT RING | Max EUD | | 5300 | | | 3 | -- | 1 |
| AVOID STREAK | Max EUD | | 4000 | | | 3 | -- | 1 |
| AVOID STREAK | Max Dose | | 5000 | | | 1 | -- | |
| 6500 (DMPD)_1 | Max Dose | | 6150 | | | 10 | -- | |
| PTV5250_OPT | Uniform Dose | | 6150 | | | 1 | -- | |
| NEED 52 | Min Dose | | 5400 | | | 1 | -- | |
| 6000 (DMPD)_1 | Max Dose | | 6150 | | | 55 | -- | |
| PTV5250_OPT | Max DVH | | 5700 | 4 | | 10 | -- | |
| [illegible] | Min Dose | | 5400 | | | 15 | -- | |

## PriOpt, Step 1

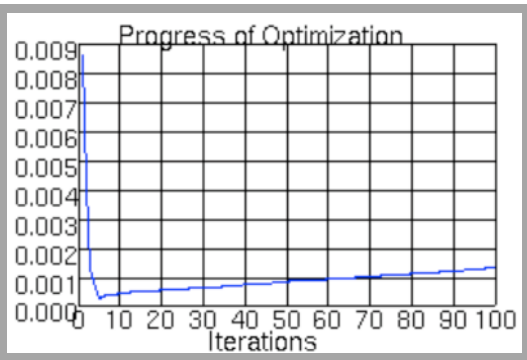
| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| CORD | Max Dose | ☑ | 4500 | | | | -- | |
| BRAINSTEM | Max Dose | ☑ | 5000 | | | | -- | |
| PTV 5580 | Min DVH | | 6000 | 98 | | 1 | -- | |
| PTV 5250 | Min DVH | | 5250 | 98 | | 1 | -- | |
| 2CM OUT_60 | Max EUD | | 4500 | | | 1 | -- | 10 |

## PriOpt, Step 2

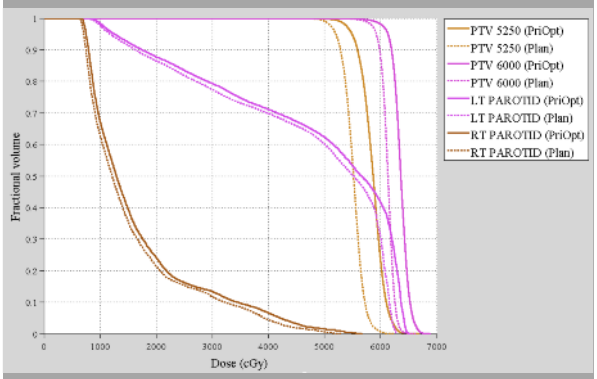
| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a | gEUD |
|---|---|---|---|---|---|---|---|---|---|
| CORD | Max Dose | ☑ | 4500 | | | | 1.30191e-07 | | |
| BRAINSTEM | Max Dose | ☑ | 5000 | | | | 2.43115e-09 | | |
| PTV 5580 | Min Dose | ☑ | 5580 | | | | 8.78213e-07 | | |
| PTV 5250 | Min Dose | ☑ | 4950 | | | | 1.19567e-07 | | |
| 2CM OUT_60 | Max EUD | ☑ | 4600 | | | | 1.23133e-07 | 10 | 4603.61 |
| LT PAROTID | Max EUD | | 4000 | | | 1 | 0.00270102 | 1 | 4464.85 |
| RT PAROTID | Max EUD | | 1200 | | | 1 | 4.14136e-05 | 1 | 1217.27 |

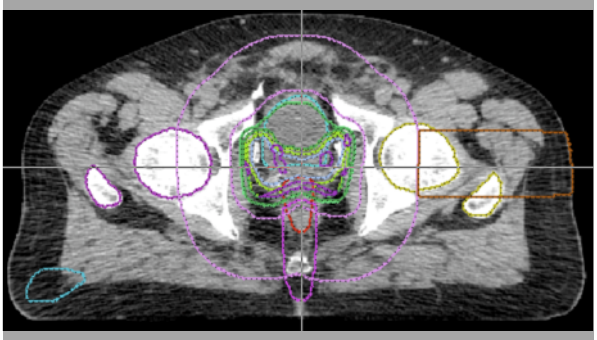
## PriOpt, Step 3 (last step)

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| CORD | Max Dose | ☑ | 4500 | | | | -- | |
| BRAINSTEM | Max Dose | ☑ | 5000 | | | | -- | |
| PTV 5580 | Min Dose | ☑ | 5580 | | | | -- | |
| PTV 5250 | Min Dose | ☑ | 4950 | | | | -- | |
| 2CM OUT_60 | Max EUD | ☑ | 4600 | | | | -- | 10 |
| LT PAROTID | Max EUD | ☑ | 4500 | | | | -- | 1 |
| RT PAROTID | Max EUD | ☑ | 1250 | | | | -- | 1 |
| 2CM OUT_60 | Max EUD | | 3200 | | | 1 | -- | 2 |
| PTV 5250 | Target EUD | | 5250 | | | 1 | -- | 1 |
| PTV 5580 | Target EUD | | 6000 | | | 1 | -- | 1 |




Slow!



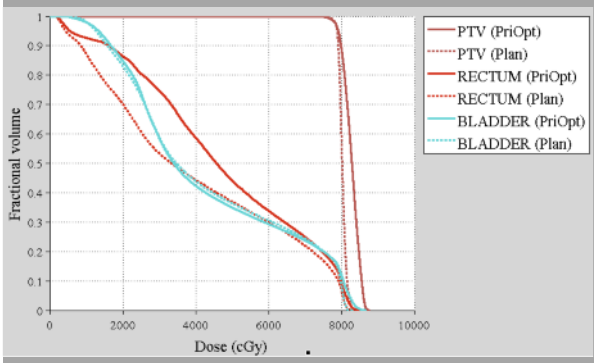



## Prostate objectives

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| LTPAROT_OPT | Max EUD | | 1950 | | | 1 | -- | 1 |
| RTPAROT_OPT | Max EUD | | 1400 | | | 1 | -- | 1 |
| POST AVOID | Max Dose | | 4000 | | | 1 | -- | |
| 2CM OUT_60 | Max EUD | | 3200 | | | 2 | -- | 1 |
| [illegible] | Max EUD | | 2700 | | | 1 | -- | 1 |
| MANDL_OPT | Max EUD | | 2750 | | | 1 | -- | 1 |
| ORALCAV_OPT | Max EUD | | 3850 | | | 1 | -- | 1 |
| 2CM OUT_60 | Max Dose | | 5800 | | | 4 | -- | |
| [illegible] | Max Dose | | 4600 | | | 2 | -- | |
| OUTSIDE RING 1 | Max Dose | | 6175 | | | 1 | | |
| [illegible] | Max Dose | | 6662 | | | 1 | | |
| [illegible] | Min Dose | | 7675 | | | 1 | | |

## Prostate PriOpt Step 3 (final step)

| ROI | Type | Constrain | Target cGy | % Volume | % Variation | Weight | Objective Value | a |
|---|---|---|---|---|---|---|---|---|
| OUTSIDE RING 1 | Max DVH | ☑ | 6175 | 2 | | | -- | |
| PTV | Max Dose | ☑ | 8662 | | | | -- | |
| PTV | Min DVH | ☑ | 7875 | 98 | | | -- | |
| RECTUM | Max EUD | ☑ | 6180 | | | | -- | 5 |
| BLADDER | Max EUD | ☑ | 6180 | | | | -- | 5 |
| OUTSIDE RING 1 | Max EUD | ☐ | 2000 | | | 1 | -- | 2 |
| OUTSIDE RING 2 | Max EUD | ☐ | 5000 | | | 1 | -- | 10 |
| extern_minus_ptv | Max Dose | ☑ | 4500 | | | | -- | |




## Issues

- Can be slow
- Automation (scripting) may be hampered by the need to keep the objective function from 'blowing up'. That is, objectives shouldn't be too far off what was available from earlier steps.

## Where is the biology?

- In the prioritization!
- Relax target homogeneity constraints…
- …but protect target minimum dose requirements
- Use gEUD with relatively high a value for rectum and bladder (a = 5).
- We can use simple objective functions because of the constrained optimization framework.

# Automated IMRT plan generation for prostate cancer

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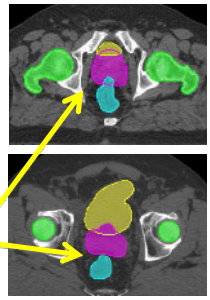
## Methods

- Autoplanning routines were created in the Philips Pinnacle treatment planning system using "scripts."
- The "scripts" are a set of internal commands stored as text files, which can be invoked on a new patient or plan.

Check for PTV and OARs
↓
Create optimization structures
↓
Set the dose grid and prescription
↓
Configure the beams
↓
Create an initial set of objectives for optimization

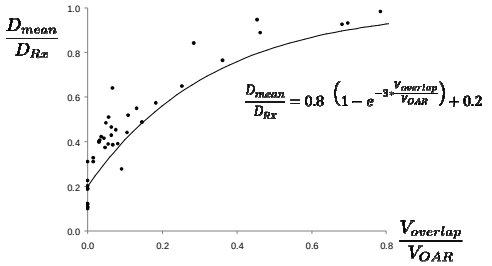
## Setting the initial objectives

- Target objectives
- Non-overlap structures
  - Set maximum dose tolerances for the organ
    - e.g. Femurs
- OARs overlapping or abutting the target
  - The minimum achievable mean dose estimated
    - e.g. Bladder and Rectum

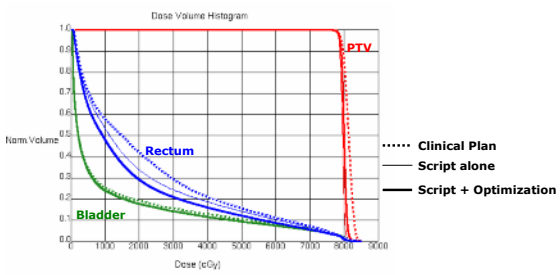


## Determination of objectives

K. Moore, *et al*. "Automated Quality Control of Clinical IMRT Planning" ICCR 2010



## Results




## Conclusions

- The automated solution showed overall improvements in quality relative to the clinically approved plan.
- The script also improved efficiency
  - Two cases required no additional optimizations
  - Remaining cases required minimal effort (10 min - 3 hours)
- Future work will focus on improving the overlap model, and further improvements in the autoplanning script

## Final remarks

- Constrained optimization (WUSTL, U Mich) reduces guesswork in treatment planning
- Current Pinnacle constrained optimization algorithm needs more development to become an efficient clinical tool.
- Other approaches (WUSTL, McNutt et al.) are leading to reliably good plans with reduced need for 'tweaking'