Optimizing “A” Values & Priorities for Efficient Head & Neck Plans

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AAMD 43rd Annual Meeting  
June 21st, 2018
Time Crunch on Planning

- Pt lost weight: need a plan by tomorrow
- Pt teeth extracted: need a new plan
- New PET findings, I have to adjust the PTVs: new plan
- I wanted to change the dose/fx scheme to help me sleep at night: NEW PLAN
- Caught a dose constraint that I forgot to mention during planning, oh and QA needs to be done by tonight: REPLAN
- I adjusted my PTV, it should be a quick rerun
- I finished the contours, pt Vsim is tomorrow: FUN PLAN
- Going on vacation, can you get a plan done? (CT sim Monday Contours done Thursday → patient V5 Friday) = WHY PLAN?

Error prone

Have you?

- Good old push structures
- Cropping OARs

- Rings
- Shells
- Rings+shells
  - SHIRINGS
Have you?

• Trying to squeeze the 20Gy line to help meet the mean dose of parotids

Have you?

• Made a dummy structure to help push where you can without compromising
Still many dummy structures...
Outline

- What is gEud?
- HN field parameters refresher
- Parotid $\alpha$ values
- Spinal Cord $\alpha$ values
- Comparing clinical accepted plans
- Discussion
- $\alpha$ guidelines for OAR/PTV structures
What is gEUD?  GENERALIZED EQUIVALENT UNIFORM DOSE

It's the homogeneous distribution that gives a biological effect equivalent or cell kill to that of a given heterogeneous dose distribution over the same fractions.

\[(\sum_i \nu_i D_i^a)^{1/a}\]

\(V_i = \) fractional organ getting dose \(D_i\)
\(A = \) tissue-specific parameter that describes the volume effect

TG-166
gEud

What it does?
• Maintains PTV coverage while maximizing normal tissue constraints
• Less dummy structures
• Helps save time

• Lower gEud - Defines an exact minimum Uniform dose for PTV
• **Target gEud** - Defines an exact Equivalent Uniform dose for PTV
  
  • *penalizes the cold spots

• **Upper gEud** - Defines an exact Equivalent maximum dose for organs at risk
  
  • Higher a value = pushes on max dose
• **Upper gEud**
  • Lower value = majority of DVH

**gEud Values**

• Why such a broad range??  
  • (-40) to (+40)  
  • Too much to choose from

*Smoothing levels used to be Levels 1 to 4!
\( \alpha \) values

Coverage \[\text{(-40, +40)}\]

\( A = 1 \)

Hotspots

PTV

OAR

\( \alpha \) values

<table>
<thead>
<tr>
<th>Organ</th>
<th>( \alpha ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV</td>
<td>-10</td>
</tr>
<tr>
<td>GTV</td>
<td>-10</td>
</tr>
<tr>
<td>Cord</td>
<td>20</td>
</tr>
<tr>
<td>Parotid</td>
<td>1</td>
</tr>
<tr>
<td>Rectum</td>
<td>8</td>
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<tr>
<td>Bladder</td>
<td>8</td>
</tr>
<tr>
<td>Mandible</td>
<td>10</td>
</tr>
<tr>
<td>Femoral head</td>
<td>12</td>
</tr>
<tr>
<td>Brainstem</td>
<td>16</td>
</tr>
<tr>
<td>Chiasm</td>
<td>16</td>
</tr>
<tr>
<td>Eye</td>
<td>16</td>
</tr>
<tr>
<td>Optic nerve</td>
<td>16</td>
</tr>
</tbody>
</table>

TG-166
• Mean value defaults to same dose constraint as gEud
Test cases

5 Head & Neck Patients

• Hypopharynx/Base of Tongue/Tonsil/Nasopharynx
• Bilateral PTV
  • T2/N2B-T4T3
  • 200x35fx SIB
    • 70Gy - RED
    • 63Gy - BLUE
    • 58.10Gy - YELLOW

Parotids Planned for a= 0.1-10,15,20,25,30,35
Priority: 65, *then replan at increasing priority

Spinal Cord a=5,10,15,20,25
Priorities: 65-120
Working my way up α values

Parotid overlap: 20-50%

GOALS

• Criteria: Keeping PTV close to
  • V95 = 95%
  • V100 = 90%
  • d99 = 100%

• Minimize OAR max/mean dose
GOALS

1. To find the optimal α value to push OAR structure

2. Balance optimization priority vs α value
   • Keep the optimization priorities consistent

3. Pushing the dose constraint without compromising PTV coverage

4. Avoid adding dummy contours before and after iteration

5. Replanned with new dose constraints
   • Copied again with planners’ scaled numbers
   • Replanned 300+ scenarios

Pre-planning

• PTVs (70/63/5810@ 2Gy per fx)
  • PTV opt 3mm from one another
    • PTV70- RED
    • PTV63- BLUE
    • PTV 58.10- YELLOW
• Off skin 3mm
• No optimized structures for OARs
Cropping structures

Eclipse 13.6
• 2 full arcs
• Geometric isocenter placed around larynx
• Collimator ~10 degrees
• Max jaw 15 cm

Foglia, A. 2017 On the gEUD biological optimization objective for organs at risk in Photon Optimizer of Eclipse treatment planning system
Normal Tissue Constraints

- NTO example:
  - Start dose at 100%-90%;
  - End dose: 50%
  - Fall off: 0.1-0.3
  - Distance from border 1.0-0.2
- Automatic is fine too

Optimization

- Starting Ratios
  - PTV -100% (ex:150)
  - OAR -33% (ex: 50)
- If only unilateral OAR can go > 50% of PTV priority
Add more than one upper and one lower for the target

Make it work!

QUANTEC constraints

- **Parotids**
  - Bilateral
    - Mean dose < 25Gy (reduces risk < 20%)
    - Mean dose < 39 Gy (reduces risk < 50%)
    - D20cc < 20Gy
  - Unilateral
    - Mean < 20Gy (reduces risk < 20%)
    - D50 < 30Gy
  - Endpoint:
    - Severe Xerostoma (long term salivary function < 25% baseline)
Started with constraints to work the optimizer
- OARs having same priority except what we wanted to work on

- Looked at 26Gy as mean goal
- Entered upper constraints as markers
- Rerun with different $\alpha$ values
• Try to hold at MR 2 step ½ to help flatten out

Results

Parotid = 30% overlap
Results

Parotid 49% overlap

Results

a=1
Results

- What about just increasing priority?
- Sure, but lose homogeneity
MD wants parotids mean ~26Gy, but likes the PTV coverage
* Added extra gEud without climbing the priority ladder

<table>
<thead>
<tr>
<th>Parotid_L</th>
<th>49.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper gEUD</td>
<td>2200</td>
</tr>
<tr>
<td>Upper gEUD</td>
<td>4400</td>
</tr>
<tr>
<td>Upper gEUD</td>
<td>2000</td>
</tr>
</tbody>
</table>
QuanteC constraints

- Spinal Cord
  - Endpoint: Myelopathy
  - Dmax
    - 50Gy: 0.2%
    - 60Gy: 6%
    - 69 Gy: 50%
  - Emami: TD 5/5: 1/3 50Gy

<table>
<thead>
<tr>
<th>Parotid Lt</th>
<th>2619 cGy</th>
<th>Parotid Rt</th>
<th>2687cGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parotid Lt (gEud)</td>
<td>2634 cGy</td>
<td>Parotid Rt (gEud)</td>
<td>2682cGy</td>
</tr>
</tbody>
</table>
How low can I pull the tail while maintaining coverage?

Opt Structure vs gEud
Spinal cord max | 3387.4 cGy
Spinal cord max (gEud) | 2497.9 cGy

PTV Coverage/Cord Sparing vs Priority/a-Value
A beautiful dance, balancing constraints
Penalizes cold spots
Trying to get more uniform coverage

<table>
<thead>
<tr>
<th>Target gEud</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper</td>
<td>0.0</td>
</tr>
<tr>
<td>Upper</td>
<td>1.0</td>
</tr>
<tr>
<td>Lower</td>
<td>10.0</td>
</tr>
<tr>
<td>Lower</td>
<td>10.0</td>
</tr>
<tr>
<td>Lower</td>
<td>0.0</td>
</tr>
<tr>
<td>Target gEud</td>
<td>0</td>
</tr>
</tbody>
</table>

Looked at the target dose, Started to look at a values of -1,-10,-15,-20,-25
Target gEud

Lower gEud

- Penalizes the minimum dose
- Pushes to get the target min
• Getting close to Rx, but lose out on conformity

• Can use independently
  • Lower gEud = higher mean
NO PLACE HOLDING with priorities
w/ gEud

[Image of graph and table]

NO PLACE HOLDING with priorities
w/ gEud

[Image of graph and table]
Upper gEud for PTV

- Higher a value affects max point dose
  - Hence: inhomogeneity
- Looking to limit hotspots

- Choosing a value
  - Evaluating the hotspots, examining 105-106%
• Add a dose constraint that’s 1% less that actual dose constraint

• Started with a=20
  • Caution: Higher a value, degrades PTV coverage

**Upper gEud for PTV**
Limit 105% of PTV 6300 (6615cGy)

before

after
• Lowered hotspot
• Didn’t compromise PTV criteria

Discussion

It all comes together...

• Field setup
• Optimization technique
  • NTO
  • Uppers/lowers
  • Less iterations needed
• No dummy structures created for OAR

• We are not a set and forget!
  • DHV looks nice, but observe the isodose levels.
Discussion

- Isodoses connected between spinal cord and constrictors
- No oral cavity was drawn in example
- Hard to work if contours aren’t congruent
Discussion

- You can plan with gEud without cropping
  - But more inhomogeneous dose
  - Need to renormalize
- Crop without buffer
  - Lost coverage on sup/inf interface

Evaluate which structure you want to push
### MU DIFFERENCES

<table>
<thead>
<tr>
<th>Patient</th>
<th>Approved MU</th>
<th>gEud Mus</th>
<th>% diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>673</td>
<td>585</td>
<td>15%</td>
</tr>
<tr>
<td>2</td>
<td>610</td>
<td>541</td>
<td>12.8%</td>
</tr>
<tr>
<td>3</td>
<td>578</td>
<td>557</td>
<td>3.7%</td>
</tr>
<tr>
<td>4</td>
<td>456</td>
<td>450</td>
<td>1.3%</td>
</tr>
<tr>
<td>5</td>
<td>556</td>
<td>537</td>
<td>3.5%</td>
</tr>
</tbody>
</table>

### Use your numbers!

- Don’t change what you do as far as priority max
  - Change the ratios
    - OAR: 33-50% off your max PTV priority
    - PTV: 67-100% off your max PTV priority
    - Can’t use base 10 because there’s no 3.3 priority

- Decide which structures you need to focus on
  - Use common sense

Starting point. We are all pushing the envelope.
GUIDELINES

- Using gEud helps limit dummy structures.
- It’s ok to mix DV and gEud constraints.
- OAR Uppers
  - Can use multiple $\alpha$ values
  - 0.7 for parallel organs maintains coverage
  - 15 for serial organs
- PTV target/upper
  - 2 for 25 rule;
  - Pick upper PTV dose constraint at 103% of target dose

<table>
<thead>
<tr>
<th>STRUCTURE</th>
<th>$a$ value</th>
<th>Structure</th>
<th>Dose Optimization Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV target</td>
<td>-25</td>
<td>Parotid</td>
<td>2000</td>
</tr>
<tr>
<td>PTV upper</td>
<td>25</td>
<td>SMG</td>
<td>2500</td>
</tr>
<tr>
<td>OAR parallel</td>
<td>0.7, 3.0</td>
<td>Crico-pharyngeal</td>
<td>2800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Larynx</td>
<td>2700</td>
</tr>
<tr>
<td>OAR series</td>
<td>15</td>
<td>Cord/Braintem@1cc</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mandible@1cc</td>
<td>5000</td>
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<td></td>
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<td>Esophagus</td>
<td>2200</td>
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<tr>
<td></td>
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<td>Cochlea</td>
<td>2800</td>
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<td>Optic Nerves</td>
<td>3500</td>
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<tr>
<td></td>
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<td>Chiasm</td>
<td>3000</td>
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</table>
Special thanks to the team

THANK YOU