Treatment Planning and Special Medical Physics Consult Approaches for Reirradiation

Martha M. Matuszak, Ph.D.
Department of Radiation Oncology, University of Michigan
Disclosure

- Research Funding and Consulting, Varian Medical Systems
Motivation

• Retreatments have found an increasing role in both academic and community practices
• Many retreatment patients have multiple prior courses, separated by a few months to several years, making the evaluation complex
• Safe and quality retreatment requires a team effort, and a well-defined workflow
• Physics can provide decision making support through discussion of setup, planning, and dose summation
Reirradiation Process (Physics-Eye-View)

Reirradiation Case Identified

Is Prior Dose Relevant?

Yes

Gather key info on prior and current tx
Date, Dose, Fractionation, Site

Determine goals of SMPC and if proper data is available to meet them

No

Document that case has prior radiation and why further workup not required

Provide guidance on overlap avoidance, planning goals, and then perform a final composite dose evaluation (if needed)

Initiate a special medical physics consult (SMPC) to evaluate prior dose, give planning recommendations, and/or evaluate dose summation
Date, Target Area, Target Dose, # Fx, Local/Outside Records, and other relevant details

Goal of Med Phys Consult (assess overlap, guidance on planning goals, composite evaluation)

Fractionation Scheme for Current Tx

For OARs of Concern:

- \( \alpha/\beta \), Total Dose Limit in EQD2, Previous Dose Discount to Apply

- Recommend a standard set of values
- Limits may change based on the goal of reirradiation and patient factors
- Little data to determine discounts, but consistency can help foster clinical confidence and data gathering
Dose Discounts

- Composite dose limits specified in EQD2
- This limit includes all relevant prior treatment, and all applicable discounts
- Discount factors are from limited data in the literature and the consensus between members of the retreatment committee
Biological Corrections

• To put variable fractionation schemes onto equal footing, a biological dose correction is needed

• Biologically corrected doses are often quoted in Biologically Effective Dose (BED) and Equivalent Dose in 2 Gy Fx (EQD2), with EQD2 being the easiest to interpret for normal tissue limits
  • See AAPM TG166 for an overview and how biological quantities may be used in treatment planning

\[
EQD2 = D \left[ \frac{(d+(\alpha/\beta))}{(2+(\alpha/\beta))} \right]
\]

• The linear quadratic model is the most widely applied and accepted scheme in various animal and human models of tumor and normal tissues despite controversy at very high dose per fraction (>10-15 Gy)
The Linear-Quadratic Model Is an Appropriate Methodology for Determining Isoeffective Doses at Large Doses Per Fraction

David J. Brenner PhD, DSc

The Linear-Quadratic Model Is Inappropriate to Model High Dose per Fraction Effects in Radiosurgery

John P. Kirkpatrick MD, PhD, Jeffrey J. Meyer MD, Lawrence B. Marks MD
Provide Planning Guidance

• A key role physics can play is to determine dose goals to pass to the dosimetrist and suggest treatment planning strategies

• Remaining Dose Allowed in EQD2] = [OAR Dose Limit in EQD2]- [Discounted Dose to OAR from Prior Tx in EQD2]

• Then, convert back to physical dose so the dosimetrist can use in the treatment planning systems (very few planning systems allow planning input in EQD2)
Methods to Determine Dose Limits

Max Dose Summation

1. Determine max dose to OAR of interest in prior plan
2. Convert to EQD2
3. Obtain EQD2 composite dose limit and any prior dose discount from physician or standardized planning document
4. Calculate the allowed dose to each OAR of interest for new plan in EQD2
5. Convert back to physical dose to give to dosimetry

Registration Based Dose Summation

1. Convert all voxel doses to EQD2
2. Register prior and current planning scans
3. Transfer prior dose to current scan
4. Determine spatial locations of maximum doses and generate sparing regions as needed for planning
## Methods to Determine Dose Limits

<table>
<thead>
<tr>
<th>Max Dose Summation Pros/Cons</th>
<th>Registration Based Dose Summation Pros/Cons</th>
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</thead>
<tbody>
<tr>
<td>• Simpler &amp; Faster</td>
<td>• Allows determination of spatial features of dose distribution and summation</td>
</tr>
<tr>
<td>• Prior Dose/DICOM not needed</td>
<td>• More accurate but potentially less conservative approach</td>
</tr>
<tr>
<td>• Conservative</td>
<td>• Requires Dose/DICOM and commissioned registration and dose summation procedure</td>
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</table>
Physicist recommendations prior to planning:

When needed, work with dosimetry to construct plan sum representing prior dose. Indicate particular issues to be mindful of in planning for this course. Note that in some cases it may make sense to provide total dose in physical dose in addition to EQD2, as well as to provide biocorrected DVH’s for physician review.

<table>
<thead>
<tr>
<th>Comments:</th>
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New allowed doses based on initial assessment:

<table>
<thead>
<tr>
<th>OAR Name</th>
<th># of Fx</th>
<th>Total Dose (Gy)</th>
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</table>
Abdominal Reirradiation Example
Abdominal Reirradiation Example (Max Dose Method)

<table>
<thead>
<tr>
<th>Plan &amp; Structure</th>
<th>n (# fx)</th>
<th>d (dose/fx)</th>
<th>D (total dose)</th>
<th>α/β</th>
<th>BED</th>
<th>EQD2</th>
<th>Discount</th>
<th>Adjusted EQD2</th>
<th>Total EQD2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior Duodenum Dose</td>
<td>5</td>
<td>2.40</td>
<td>12.00</td>
<td>2.5</td>
<td>23.52</td>
<td>13.07</td>
<td>0.20</td>
<td>10.45</td>
<td></td>
</tr>
<tr>
<td>Current Duodenum Goal</td>
<td>8</td>
<td>3.85</td>
<td>30.84</td>
<td>2.5</td>
<td>78.38</td>
<td>43.54</td>
<td>0.00</td>
<td>43.54</td>
<td></td>
</tr>
</tbody>
</table>

Guidance for Dosimetry since they (usually) need physical doses for planning
Abdominal Reirradiation Example

• Extreme Changes in Geometry
  • Is it worthwhile, beneficial, or a good use of clinical time to perform deformable registration followed by dose summation?

• Quick observations: Dose is in the same plane – likely that the same OAR tissue will receive dose
  • Likely not safe to simply avoid or minimize overlap

• Compute allowed doses in current treatment using EQD2 doses, time discounts, and EQD2 limits

• If useful for some OARs, deformable or rigid registration can be used globally or locally
Lung Reirradiation Example

• 60 yr old man who originally presented with increased cough
• Workup revealed a 9.4 x 5.1 x 5.9 cm RLL mass encasing the bronchus intermedius with ipsilateral hilar and multilevel mediastinal lymph node involvement
• Concurrent chemoradiation with RT to right lung and mediastinum: 60 Gy in 2 Gy fractions
  • Plan was adapted for the final 14 Fx (daily CBCT)
• Re-presented 3 years later with worsening cough and found to have in field recurrence threatening bronchial airway closure
Prior RT Analysis & Reconstruction

• Will the prior RT be relevant?
  • If yes, do we mainly care about maximum doses to an organ or would we like to see the composite dose distribution?
  • To get the composite dose distribution and DVHs, the dose and CT must be accessible
    • Available in the local planning system or imported from another institution via DICOM
    • Caution for older cases: Prior dose distribution could be an older, less accurate dose calculation or could have not used density corrections
Lung Example – Assess Prior RT

Plan 1 – Delivered 16/30 Fx (2 Gy/Fx)

Plan 2– Adapted for Final 14 Fx (2 Gy/Fx)
Lung Example – Assess Prior RT

• Prior plans local, but in a different planning system
• Transferred to current planning system via DICOM export
• Recalculated in current planning system using the actual MU delivered
  • Sanity check with paper records
• Dose summation on one dataset after rigid registration
Lung Example – Assess Viability of a Dose Summation

Without deformable registration – must focus on most critical areas of interest – in this case it was the spinal cord
Lung Example – Composite Dose Limits and Details

• What structures will be receiving significant composite dose?

• For each structure:
  • What is the composite dose limit in EQD2 (or physical dose, if all plans are equal fractionation)?
  • For EQD2 dose summation, what is the structure $\alpha/\beta$ ratio?
  • How much, if any, should you discount prior RT?
• Primary structures of interest – Esophagus, Cord, Heart
• Secondary structure of interest – Lungs-GTV
• Initial plan for retreatment was meant to be simple 3DCRT at 30 Gy in 10 Fx
• Composite dose for Esophagus and Heart with a simple 3DCRT plan were > 90 Gy EQD2
• Utilized VMAT to better spare OARs
Final Dose Summation

- Final evaluation to verify dose summation and **document** the composite doses in EQD2 is helpful to grow our knowledge about toxicity and retreatment tolerances.
- Some commercial tools are available, but should be properly commissioned.
  - Deformable or rigid dose summation
  - LQ and other biological corrections
- In-house tools are also common, including those tied to the planning system.

<table>
<thead>
<tr>
<th>Metric</th>
<th>2.1 RTLUNG VM</th>
<th>0.5*C1+C2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Esophagus1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D0.1cc[Gy]</td>
<td>21.52 Gy</td>
<td>52.46 Gy</td>
</tr>
<tr>
<td>D0.1cc(LQ, α/β=2.5)[EQD2Gy]</td>
<td>22.27 Gy (LQ2)</td>
<td>53.81 Gy (LQ2)</td>
</tr>
<tr>
<td><strong>Bronchus_Main</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D0.1cc[Gy]</td>
<td>33.47 Gy</td>
<td>62.92 Gy</td>
</tr>
<tr>
<td>D0.1cc(LQ, α/β=2.5)[EQD2Gy]</td>
<td>43.47 Gy (LQ2)</td>
<td>72.61 Gy (LQ2)</td>
</tr>
<tr>
<td><strong>SpinalCord</strong></td>
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</tr>
<tr>
<td>D0.1cc[Gy]</td>
<td>15.93 Gy</td>
<td>30.67 Gy</td>
</tr>
<tr>
<td>D0.1cc(LQ, α/β=2.5)[EQD2Gy]</td>
<td>14.48 Gy (LQ2)</td>
<td>25.67 Gy (LQ2)</td>
</tr>
</tbody>
</table>

*In-house script to perform voxel based LQ correction and dose summation in registered datasets.*
Physicist analysis after completion of final plan (optional)

Use DVHAnalysis to assess Dose Metrics indicated by physician on composite plan if available. If plan sums were not possible, provide narrative indicating estimations of requested doses where possible.

Comments: 

Final Physician Acknowledgement:

Approval of this document acknowledges the work performed. Additional comments may be added below if desired.
Patient Setup Considerations

• Patient setup, immobilization, and motion management utilized for the prior treatment should be considered at the time of patient simulation for retreatment.

• Standard motion management strategy or immobilization that may be ideal for a case, could negatively impact the positioning of treatments in a retreatment scenario.
Free-breathing L1 spine SBRT (2018)
Breath-hold scan for retreatment 2019
Breath-hold scan for retreatment 2019
Breath-hold scan for retreatment 2019
Challenges in Clinical Practice

• Lack of data/guidance on dose limits and discounts
• Uncertainty on when to apply deformable registration (and the benefits and limitations)
• Lack of tools for voxel based biological corrections and treatment planning using EQD2 objectives
• Lack of knowledge on proper way to sum dose distributions
• Contouring and nomenclature changes over time can make dose evaluation very complicated, requiring rework and careful review
Summary/Take Home Points

• Retreatment is common in many practices and will only increase.

• Simple biological corrections using the linear quadratic model can be powerful tools for dose summation and retreatment decision making.

• Caution must be taken to evaluate the case as a whole – there are many uncertainties that arise in retreatment scenarios due to geometries, corrections, and modeling.

• Standardized procedures, dose limits, and discounts are a good starting point for establishing a reirradiation service – it is a team effort.
Acknowledgments

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Thank You