Stereotactic Body Radiation Therapy (SBRT) – One Dosimetrist’s Experience
What is SBRT?

- Stereotactic
- Body
- Radiation
- Therapy
Stereotactic

- Stereotaxy = the superposition of a 3D co-ordinate system upon a given organ or structure.
- Requires an external frame, fixed to the body and treatment apparatus.
- The cranium is really the only site this is practical for.
SBRT Definition
Body

• This seems like an odd descriptor of radiation therapy… isn’t it all given to the body?
• Body = Extracranial
Radiation Therapy

• Hopefully, we all have some idea what this is… or do we…?
Standard Radiation Therapy
• Developed over the last 70 years
• Fractionated
• Daily Dose 1.8 – 2.0 Gy
• 2 – 4 Fields
Standard Radiation Therapy

- Functions by disrupting cellular division
- Cellular division is a complex process
- Disruption of any part of this process can lead to loss of reproductive integrity
- “Multiple high-value targets”
Fig. 1. a Typical cell survival curve shape comparing single-dose and multiple-dose radiation exposure. b Cell survival differs between normal tissues and tumor tissues for multiple-fraction exposure.

Meyer, et al. 2007
Standard Radiation Therapy

• Why fractionate?
  • Normal Tissue
  • Increasing dose / fraction using traditional techniques usually leads to increased toxicity
  • Traditional techniques included too much normal tissue
SBRT

- Delivery of high dose in few fractions
- SBRS (Stereotactic Body Radio Surgery) = 1 fraction
- SBRT = 2 – 5 fractions
SBRT Definition

SBRT

• Functions by destroying target cellular function
• Any individual cellular function is typically simpler than cellular reproduction… but all of functionality must be destroyed
• “Cumulative loss of low-value targets”
SBRT

• We need to be able to deliver high dose / fraction without toxicity

• Changes to
  • Simulation
  • Treatment Planning
  • Treatment Delivery
SBRT Simulation

- Immobilization
  - Body frames / bags – indexable
- High resolution CT (0.25cm or less)
- Respiratory Motion
  - Compression plates / wraps
  - Respiratory Gating – prospective or retrospective
SBRT Treatment Delivery

- High accuracy daily target localization
- IGRT
  - CBCT
  - kV / MV imaging
  - Ultrasound
• High accuracy target definition
  • Internal Target Volume (ITV) construction considering the role of respiratory motion
• Highly conformal dose volumes
  • Multiple beams (7 – 11), IMRT, VMAT
• Sharp dose gradients
  • Small field sizes, dose prescription to low isodoses, acceptance of dose inhomogeneity inside target
RPCI SBRT Experience

- Started our SBRT Lung program in 2007
- We also treat:
  - Liver
  - Adrenal / Kidney
  - Spinal Metastases
  - Head and Neck
- As of Sept 1 2016 – 536 cases
Lung SBRT Experience

- Lung SBRT (approx. 90% of cases)
- Follow RTOG protocols
  - 0236
  - 0813
  - 0915
- Developed internal protocols and clinical trials based upon the RTOG studies
• Target Definition
  • ITV is constructed based upon evaluation of the respiratory motion
  • Binned into 10% increments of respiratory cycle
  • Segments with too much motion are not used for ITV generation and will not be treated
  • PTV = ITV + 0.5cm
Lung SBRT Guidelines

• Dose Constraints – Target
  • High conformality, sharp dose gradients
  • Dose is typically prescribed to the highest isodose value that:
    • Covers 95% of PTV
    • Is between 60% and 90% of prescription dose
  • Why 60 – 90%?
    • Field conform to target with virtually no margin - 95% cannot cover volume
    • Field sizes must be kept as small as possible to spare normal tissue
Lung SBRT Guidelines

- Dose Constraints – Target
  - High Dose Conformality
    - 95% of PTV covered by 100% of prescription dose
    - 99% of PTV covered by 90% of prescription dose
  - High Dose Spillage
    - 100% Conformality Index
      - Ratio of prescription dose volume / PTV volume less than 1.2
    - Volume of tissue outside the PTV exceeding 105% must be less than 15% of PTV volume
Lung SBRT Guidelines

- Dose Constraints – Target
  - Low Dose Spillage
    - 50% Conformality Index
      - Ratio of 50% prescription dose volume / PTV volume
      - Value varies based upon PTV volume
      - Lower acceptable limit as PTV volume increases
      - Range 2.9 – 3.9
    - Maximum Dose 2cm from PTV
      - Value varies based upon PTV volume
      - Higher acceptable limit as PTV volume increases
      - Range 46.8 – 73.8 % rx dose
• Dose Constraints – Organs at Risk
  • Standard dose constraints don’t work due to:
    • High dose / fraction
    • Different mechanisms of cell damage
  • Data from earlier protocols that resulted in “good” plans was used to determine dose limits, which are then modified according to total prescription dose
### Lung SBRT Guidelines

**Dose Constraints – Organs at Risk**

<table>
<thead>
<tr>
<th>Constraints</th>
<th>RTOG 0236 60 Gy / 3 Fx</th>
<th>RTOG 0813 50 – 60 Gy / 5 Fx</th>
<th>RTOG 0915 34 – 48 Gy / 1 – 4 Fx</th>
<th>RPCI I-124407 30 – 60 Gy / 1 – 3 Fx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung V20</td>
<td>10 %</td>
<td>10 %</td>
<td>10 %</td>
<td>10 %</td>
</tr>
<tr>
<td>Lung V12.5</td>
<td></td>
<td>1500 cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung V13.5</td>
<td></td>
<td>1000 cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lung V7</td>
<td></td>
<td>1500 cc</td>
<td>1500 cc</td>
<td></td>
</tr>
<tr>
<td>Lung V7.4</td>
<td></td>
<td>1000 cc</td>
<td>1000 cc</td>
<td></td>
</tr>
<tr>
<td>Spinal Cord Max</td>
<td>18 Gy</td>
<td>30 Gy</td>
<td>14 / 26 Gy</td>
<td>14 / 18 Gy</td>
</tr>
<tr>
<td>Spinal Cord V13.5</td>
<td></td>
<td>0.5 cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal Cord V7</td>
<td></td>
<td>1.2 cc</td>
<td>1.2 cc</td>
<td></td>
</tr>
</tbody>
</table>
• Planning Techniques

<table>
<thead>
<tr>
<th></th>
<th>Standard 3DCRT</th>
<th>SBRT</th>
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<tbody>
<tr>
<td>Prescription</td>
<td>60 – 66 Gy</td>
<td>30 – 60 Gy</td>
</tr>
<tr>
<td>Dose / Fx</td>
<td>1.8 – 2.0 Gy</td>
<td>10 – 30 Gy</td>
</tr>
<tr>
<td>GTV / ITV Determined by</td>
<td>Free Breathing / Breath Hold CT</td>
<td>Respiratory Phase Analysis</td>
</tr>
<tr>
<td>PTV</td>
<td>GTV + 1.0 – 1.5cm</td>
<td>ITV + 0.5cm</td>
</tr>
<tr>
<td>Technique</td>
<td>2 – 4 Fields</td>
<td>7-11 Fields</td>
</tr>
<tr>
<td>Block Margin</td>
<td>0.8 – 1.2cm</td>
<td>0.0 – 0.2cm</td>
</tr>
</tbody>
</table>
Lung SBRT vs 3DCRT

- Targets

3D CRT

SBRT
Lung SBRT vs 3DCRT

• 95% Isodose Coverage
Lung SBRT vs 3DCRT

- 50% Isodose Coverage
Lung SBRT vs 3DCRT

- Low Dose Coverage (7 Gy)
My SBRT Experience

- Started planning Lung SBRT in 2009
- Started planning much more frequently in 2011
- Presentation Data
  - 70 cases
  - 2011 – 2016
  - 3D and VMAT
  - Heterogeneity On and Off
• Data Analysis
  • Parameters vs Time – did I get any better?
  • Parameters vs Technique – is VMAT better?
  • Parameters vs Calculation – is Heterogeneity better?
  • Parameter vs Patient Characteristics – is there a relationship between:
    – PTV volume and dose coverage
    – Total lung volume and lung parameters
My SBRT Experience

- Did I get any better?
My SBRT Experience

- Did I get any better?

**Maximum Dose Volume outside PTV + 2cm / Limit**

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Cases over Time
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![Graph showing maximum doses over time.](image-url)
My SBRT Experience

• Did I get any better?

V50% / Limit

Cases over Time
My SBRT Experience

• Did I get any better?
### My SBRT Experience

- **Is VMAT better than 3D?**

<table>
<thead>
<tr>
<th></th>
<th>3D (n = 57)</th>
<th>VMAT (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformality Index / Limit</td>
<td>0.90</td>
<td>0.83 **</td>
</tr>
<tr>
<td>Max Dose PTV +2cm / Limit</td>
<td>0.97</td>
<td>0.94</td>
</tr>
<tr>
<td>V50% Rx Dose / Limit</td>
<td>0.91</td>
<td>0.99</td>
</tr>
<tr>
<td>Lung V7 / Limit</td>
<td>0.27</td>
<td>0.46 **</td>
</tr>
<tr>
<td>Lung V20 / Limit</td>
<td>0.30</td>
<td>0.40 **</td>
</tr>
<tr>
<td>Time on Treatment Couch</td>
<td>35.5</td>
<td>15</td>
</tr>
</tbody>
</table>
• Is Heterogeneity correction better?
  • We plan patients with or without heterogeneity corrections based upon the protocol we are following and/or the treatment technique

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Heterogeneity Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTOG 0236</td>
<td>N</td>
</tr>
<tr>
<td>RTOG 0813</td>
<td>Y</td>
</tr>
<tr>
<td>RTOG 0915</td>
<td>Y</td>
</tr>
<tr>
<td>RPCI I-124407</td>
<td>N</td>
</tr>
<tr>
<td>All VMAT cases</td>
<td>Y</td>
</tr>
</tbody>
</table>
Is there a relationship between PTV volume and dose parameters?
My SBRT Experience

- Is there a relationship between PTV volume and dose parameters?

PTV Volume vs. V50% / V50% Limit
My SBRT Experience

• Is there a relationship between PTV volume and dose parameters?
My SBRT Experience

- Is there a relationship between PTV volume and dose parameters?
Is there a relationship between total lung volume and dose parameters?
• Is there a relationship between total lung volume and dose parameters?

Lung Volume vs. $V_7 / V_7$ Limit

![Graph showing the relationship between lung volume and $V_7 / V_7$ limit.](image)
Does SBRT Work?

- 5 months post treatment
Does SBRT Work?

- 17 months post treatment
Does SBRT Work?

• 31 months post treatment
Conclusions?

- SBRT planning is not for the faint of heart
- Plan quality seems to be largely a factor of the protocol constraints
- There “appears” to be a relationship between PTV volume and some plan parameters
  - It appears to be more difficult to achieve the V50%, Lung V20 and Lung V7 parameter as PTV volume increases
• Read the protocols – but sometimes they have English bad
• Make sure you’re using the right prescription dose / OAR parameters for the clinical situation
• Do a site visit
• Don’t get too freaked out about SBRT planning
• But don’t take it lightly
Thanks

- Rachel Hackett
- Andrew Goraj
- Jeremy Garvin
- Richard Russo
- Anurag Singh
- Jorge Gomez
Thanks

- Callum Hales
Questions?

- If you want to discuss specific technique issues, etc....
- Find me in the bar