Dosimetric Advantages of Proton Simultaneous In-field Boost (PSIB) Technique for Treating Lung Cancer

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Objectives

- To evaluate a Simultaneous In-field Boost (SIB) technique for treating lung cancer
  - To treat the high tumor burden (GTV) at a higher dose level
  - To maintain the same minimum peripheral dose to CTV
- To evaluate dosimetric benefits
  - Normal tissue doses to lung, esophagus, heart, and spinal cord.
Background

- SIB is a typical treatment technique for IMRT planning
- Is it possible to design proton SIB plans with passively scattered protons?
- What are the dosimetric benefits?
- Which site is a good application?
Examples of Stage III Lung Cancer Cases
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Examples of Stage III Lung Cancer Cases
Proton SIB (Simultaneous In-field Boost) Protocol

- **CTV 60 Gy/30fx (2Gy/ fx)**

Table 1. Dose escalation schedule for phase I part of the trial.

<table>
<thead>
<tr>
<th>Total dose (CGE)</th>
<th>No. fractions</th>
<th>Fraction dose (CGE)</th>
<th>BED (ACUTE) $\alpha/\beta = 10$</th>
<th>BED (LATE) $\alpha/\beta = 3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>nd</td>
<td>n</td>
<td>d</td>
<td>$1+ \frac{d}{\alpha/\beta}$ BED</td>
<td>$1+ \frac{d}{\alpha/\beta}$ BED</td>
</tr>
<tr>
<td>CTV dose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 CGE</td>
<td>30</td>
<td>2.0</td>
<td>1.2</td>
<td>1.67</td>
</tr>
<tr>
<td>SIB V dose</td>
<td></td>
<td></td>
<td>72</td>
<td>100.2</td>
</tr>
<tr>
<td>66 CGE</td>
<td>30</td>
<td>2.2</td>
<td>1.22</td>
<td>1.73</td>
</tr>
<tr>
<td>72 CGE</td>
<td>30</td>
<td>2.4</td>
<td>1.24</td>
<td>1.8</td>
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<tr>
<td>78 CGE</td>
<td>30</td>
<td>2.6</td>
<td>1.26</td>
<td>1.87</td>
</tr>
<tr>
<td>84 CGE</td>
<td>30</td>
<td>2.8</td>
<td>1.28</td>
<td>1.93</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>107.52</td>
<td>162.12</td>
</tr>
</tbody>
</table>
Rationale
Entrance Dose for Different SOBP Widths

G2_250MeV_RMW91_range28.5cm_mediumsnout@5cm

PDD vs. Depth (mm)

- SOBP 4 cm, Measured 4.2 cm
- SOBP 10 cm, Measured 10.2 cm
- SOBP 16 cm, Measured 16.1 cm
- SOBP 12 cm, Measured 12.0 cm
- SOBP 8 cm, Measured 8.1 cm
- SOBP 6 cm, Measured 6.1 cm
- SOBP 14 cm, Measured 14.3 cm
Parallel-opposed Two-field Arrangement
High center dose:

Low or equal peripheral dose

Small SOBP boosts central GTV dose while lowering peripheral dose.
Additional Benefit of Normalizing to a Lower Dose Level → Pushing Penumbra into the field

![Lateral Profile of Prostate](image)

- **GTV**
- **CTV**

Distance [cm] vs. Dose [cGy] graph showing the lateral profile with dose levels indicated.
14 Stage-III NSCLC cases
Results
CTV: minimum 60Gy @ 95%
GTV: 60, 66, 72, 78, 84 Gy

When GTV dose increases, Dose to normal structure does not Seem to increase much.
60 Gy vs. 84 Gy

CTV and GTV at 60 Gy

CTV at 60 Gy and GTV at 84 Gy
Mean Lung Dose Difference (Relative To the CTV60 Plan)

Average Over 14 cases
% Total Lung Volume at 5 Gy Relative To CTV60 Plan

-5
-4
-3
-2
-1
0
GTV66
GTV72
GTV78
GTV84
Percent (%)
Absolute Lung Volume Difference at 5 Gy

Volume (cc)

GTV66  GTV72  GTV78  GTV84
Absolute Lung Volume Difference at 10 Gy
Mean Heart Dose Difference

Dose (cGy)

GTV66  GTV72  GTV78  GTV84
Volume of Heart > 40 Gy

Volume (cc)

GTV66  GTV72  GTV78  GTV84
Absolute Esophagus Volume > 50 Gy

![Bar chart showing esophagus volume comparison for GTV66, GTV72, GTV78, and GTV84.](chart.png)
Maximum Cord Dose

Dose (cGy)

GTV66  GTV72  GTV78  GTV84
Mean Body Dose

Dose (cGy)

GTV66  GTV72  GTV78  GTV84
Conclusion

- Simultaneous In-field Boost (PSIB) technique is feasible with passively scattered protons.
  - Maybe a good application for lung cancer treatment.
- The method takes the advantage of a slowly-falling proximal SOBP dose distribution and large lateral penumbra to create a non-uniform dose gradient between the GTV and the CTV.
- Normal tissue toxicities are essentially unchanged from a GTV boost from 60 CGE to 84 CGE.

Thank you!