Proton Radiotherapy can Improve Lung Sparing Compare with Photon IMRT

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Background & Purpose
Chemo-radiotherapy is the preferred modality for cervical esophageal carcinoma

**PRIMARY TREATMENT**

- **Esophagectomy**[^g] (preferred for noncervical T1 disease)
- **Definitive chemoradiotherapy**
  - Medically fit[^b], resectable[^c], T1–T3, N0–1, NX, or Stage IVA
  - **RT, 50-50.4 Gy + concurrent chemotherapy (5-FU-based)**

**ADJUNCTIVE/ADJUVANT TREATMENT**

- **See Clinical Pathological Findings (ESOPH-3)**
- **Esophagectomy[^f] or Palliative treatment, including chemotherapy[^h]**
- **Palliative chemotherapy[^h] and/or endoscopic therapy**

[^g]: Medicaly able to tolerate major abdominal and/or thoracic surgery.
[^c]: Chemoradiotherapy is the preferred modality for cervical esophageal carcinoma.
[^d]: Resectable T4: involvement of pleura, pericardium or diaphragm.
[^f]: Transhiatal or transthoracic, or minimally invasive; gastric reconstruction preferred.
[^i]: Feeding jejunostomy for postoperative nutritional support, generally preferred.
[^h]: See Principles of Systemic Therapy (ESOPH-A).
[^b]: Assessment ≥ 4 weeks, endoscopy with biopsy and brushings.

Note: All recommendations are category 2A unless otherwise indicated.
Clinical Trials: NCCN believes that the best management of any cancer patient is in a clinical trial. Participation in clinical trials is especially encouraged.
Challenging of radiotherapy treatment planning
# Experience of proton radiotherapy in Esophageal cancer

<table>
<thead>
<tr>
<th>Author year</th>
<th>Patients</th>
<th>results</th>
<th>Conslusion/comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Koyama 2003</td>
<td>Superficial 13 (MD=77.7 Gy) Advanced 17 (MD=80.3 Gy)</td>
<td>OS 60.1M 100% 38.6M 49.0%</td>
<td>Upper Middle Lower Abdominal</td>
</tr>
<tr>
<td>S Sugahara 2005</td>
<td>T1, 23 T2-T4, 23 X+P=69.1-87.4Gy P=75-89.5 Gy</td>
<td>55% 95% 13% 33%</td>
<td>Upper Middle Lower Abdominal</td>
</tr>
</tbody>
</table>

OS = overall survival,  DSS = disease specific survival  
X+P = combined photon and proton, P = proton only  

Sugahara S. IJROBP. Vol. 61, No. 1, pp. 76–84, 2005
The aim of the study

- To evaluate the benefits of proton radiotherapy compare with photon IMRT
- To search proper treatment planning protocol for proton therapy
Patients & methods

- 5 patients
- TPS:
  - Varian Eclipse
- Dose criteria
  - 60Gy to 95% PTV;
  - 45 Gy to spinal cord
- OARs:
  - Lungs
  - whole lung
  - heart
  - Body (for planning comparison only)
- Comparison tools
  - Isodose distribution
  - Dose volume histogram (DVH)
Beam arrangement

Plan 1

Proton plans

Plan 2

Plan 3

Photon IMRT
## Results

Table 1. DVH data for GTV and PTV

<table>
<thead>
<tr>
<th></th>
<th>GTV</th>
<th>PTV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IMRT</td>
<td>Plan1</td>
</tr>
<tr>
<td>Dose_Min</td>
<td>51.7 (7.0)</td>
<td>42.1 (10.6)</td>
</tr>
<tr>
<td>Dose_Max</td>
<td>69.4 (2.0)</td>
<td>70.1 (4.5)</td>
</tr>
<tr>
<td>Dose_Mean</td>
<td>64.5 (0.9)</td>
<td>62.2 (3.8)</td>
</tr>
</tbody>
</table>

GTV and PTV data with Dose Min, Max, Mean, and standard deviation. The data in brackets are standard deviations.
## Table 2. DVH data for OARs

<table>
<thead>
<tr>
<th>OAR</th>
<th>IMRT</th>
<th>Plan1</th>
<th>Plan2</th>
<th>Plan3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal cord</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Max (&gt;1% volume)</td>
<td>30.9 (8.1)</td>
<td>39.5 (5.7)</td>
<td>6.9 (10.3)</td>
<td>26.4 (6.7)</td>
</tr>
<tr>
<td>Dose Mean</td>
<td>16.4 (4.2)</td>
<td>15.1 (3.6)</td>
<td>0.5 (0.8)</td>
<td>10.9 (3.4)</td>
</tr>
<tr>
<td>Left lung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Mean</td>
<td>14.4 (5.1)</td>
<td>9.0 (1.6)</td>
<td>9.8 (1.3)</td>
<td>9.6 (1.5)</td>
</tr>
<tr>
<td>V20</td>
<td>30.8 (6.6)</td>
<td>20.7 (3.9)</td>
<td>23.7 (4.9)</td>
<td>18.9 (3.9)</td>
</tr>
<tr>
<td>Right lung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Mean</td>
<td>13.8 (2.5)</td>
<td>7.7 (2.0)</td>
<td>8.1 (1.6)</td>
<td>8.1 (1.8)</td>
</tr>
<tr>
<td>V20</td>
<td>21.5 (2.8)</td>
<td>16.0 (3.8)</td>
<td>18.4 (2.6)</td>
<td>15.8 (5.2)</td>
</tr>
<tr>
<td>Total lung</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Mean</td>
<td>14.5 (2.6)</td>
<td>8.2 (1.2)</td>
<td>8.8 (0.4)</td>
<td>8.7 (1.0)</td>
</tr>
<tr>
<td>V20</td>
<td>24.9 (4.0)</td>
<td>18.1 (2.4)</td>
<td>20.8 (2.4)</td>
<td>17.4 (3.4)</td>
</tr>
<tr>
<td>Heart</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Max</td>
<td>43.1 (30.7)</td>
<td>51.9 (20.8)</td>
<td>51.4 (19.3)</td>
<td>49.9 (20.0)</td>
</tr>
<tr>
<td>Dose Mean</td>
<td>16.4 (10.9)</td>
<td>6.4 (7.4)</td>
<td>8.7 (10.9)</td>
<td>6.2 (8.1)</td>
</tr>
<tr>
<td>Dose&gt;40Gy</td>
<td>6.2 (6.3)</td>
<td>3.3 (4.0)</td>
<td>7.9 (10.6)</td>
<td>3.7 (4.7)</td>
</tr>
<tr>
<td>Body</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dose Max (&gt;1% volume)</td>
<td>66.1 (3.1)</td>
<td>63.4 (4.2)</td>
<td>63.6 (1.5)</td>
<td>62.7 (1.5)</td>
</tr>
<tr>
<td>Dose Mean</td>
<td>13.4 (1.7)</td>
<td>8.2 (1.3)</td>
<td>6.7 (1.4)</td>
<td>7.8 (1.3)</td>
</tr>
</tbody>
</table>

Data in brackets are standard deviation
Patient No. 4: DVHs for GTV and PTV
Patient No. 4: DVHs for OARs
Photon IMRTPlan3
Plan1
Plan2
Plan3
Photon IMRT
Proton plans
40%
70%
90%
Proton plans

Plan 1

Plan 2

Plan 3

Photon IMRT

2007/7/30
Proton plans

Plan 1
40%
70%
90%

Plan 2

Plan 3

Photon IMRT

2007/7/30
Conclusions

- Protons provides the possibility
  - of further sparing lungs and other OARs in cervical esophageal cancer radiotherapy;
  - to escalate radiation dose in PTV or to combine more aggressive chemotherapy.
Conclusions

- of three proton treatment protocols, each technique may be proper for different clinical situations
  - AP-PA technique can give an acceptable dose distribution both in PTV and in surrounding OARs, it is the simplest technique
  - but three beam technique decreases absorbed dose in OARs further, with acceptable work effort in the department.
  - two oblique beams technique can delivery nearly no dose to spinal cord, but increases absorbed dose in lung, therefore it is not a option for clinical purpose, except for re-treatment.