High and low dose regions to normal tissues in IMRT

Rick Haas NKI/AvL
IMRT and dose

- IMRT is focused to
  - Increase the target dose and/or
  - Decrease the normal tissue dose
- This involves multiple directions of radiation and potentially more low dose volume
- IMRT is, generally, not aiming at reducing secondary cancers
IMRT and dose

CRT

• Clark et al R&O 2004
IMRT and dose
More low dose volume

• Clark et al R&O 2004
IMRT and dose
Lung cancer dose escalation

Belderbos et al 2006
IMRT and dose lung dose and pneumonitis

Seppenwoolde 2003
IMRT and dose
FFS Prostate 68 vs 78 Gy

Peeters et al 2006
Prostate
Acute GI toxicity

<table>
<thead>
<tr>
<th>Grade ≥ 2</th>
<th>Conformal</th>
<th>SIB IMRT</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade ≥ 3</td>
<td>61 %</td>
<td>20 %</td>
<td>0.001</td>
</tr>
<tr>
<td>Grade ≥ 3</td>
<td>13 %</td>
<td>0 %</td>
<td></td>
</tr>
</tbody>
</table>
Prostate
Late GI toxicity (grade $\geq 2$)

![Graph showing cumulative incidence of late GI toxicity over time from start radiotherapy, comparing Conformal and SIB IMRT techniques.](image)
IMRT and dose

✓ Using IMRT for both lung and prostate cancer allows for dose escalation

✓ IMRT for head and neck cancer decreases side effects and increases coverage
Impact of IMRT

IMRT vs CRT: differences in dose distribution

- Increase in monitor units:
  - Larger total-body radiation dose (photon and neutron component for higher energy)
  - but no wedges, or physical compensators etc.
  - Related to delivery units (IMRT, TOMO, etc)

- Larger volume of normal tissue exposed to lower radiation: the effects related to dose-response curve for radiation induced carcinogenesis or nonmalignant toxicities

- Clinically relevant in pediatric oncology
Long Latency
late side effects and secondary cancers

Years after treatment

Risk

- Recurrence
- 2\textsuperscript{nd} primary
- Cardiac

Courtesy Hans Langendijk
IMRT and dose

- Mu et al 2005
- Pediatric case spinal cord irradiation
- RT comparison with photon, electron and proton techniques
IMRT and dose

Mu et al 2005
Fotonen versus protonen: Vergelijkende planning

Courtesy Hans Langendijk
### Estimation of secondary lethal cancers pediatric case

<table>
<thead>
<tr>
<th></th>
<th>Photon</th>
<th>IMRT</th>
<th>Electr</th>
<th>IMET</th>
<th>IMPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oesophagus</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.13</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.15</td>
<td>0.15</td>
<td>0.18</td>
<td>0.16</td>
<td>0.00</td>
</tr>
<tr>
<td>Lung</td>
<td>0.17</td>
<td>0.37</td>
<td>0.21</td>
<td>0.12</td>
<td>0.02</td>
</tr>
<tr>
<td>Mammary glands</td>
<td>0.05</td>
<td>0.12</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Liver</td>
<td>0.11</td>
<td>0.15</td>
<td>0.09</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Stomach</td>
<td>0.24</td>
<td>0.44</td>
<td>0.27</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>Abdominal cavity</td>
<td>0.23</td>
<td>0.34</td>
<td>0.24</td>
<td>0.19</td>
<td>0.02</td>
</tr>
<tr>
<td>Patient outline</td>
<td>0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Effective dose</td>
<td>1.761</td>
<td>2.696</td>
<td>1.863</td>
<td>1.326</td>
<td>0.306</td>
</tr>
<tr>
<td>Total risk of SLC</td>
<td>0.198</td>
<td>0.303</td>
<td>0.210</td>
<td>0.149</td>
<td>0.034</td>
</tr>
</tbody>
</table>
(IM)RT and dose

=> Late toxicity
Myocard infarction after mediastinal RT

Aleman 2007
Late toxicity

3-7 fold increased risk for sec. cancer after 30 Gy for testicular cancer predominantly inside the field

Leeuwen et al. 1993
(IM)RT and late toxicity

• Increased breast cancer after Hodgkin disease
  – <5 Gy no increased risk
  – >5 Gy Relative Risk 2.7 fold
  – Protective effect of chemotherapy due to early menopause

Hill et al 2005
(IM)RT, dose and volume

- Does reduction of fields reduce secondary cancer risk?
(IM)RT, dose, volume and age applied

- 1122 female patients treated with RT for Hodgkin disease
- <51 years
- Incidence of breast cancer
Breast cancer after RT for HD
Breast cancer after RT for HD

De Bruin et al submitted
Particle therapy?
Fotonen versus protonen: Vergelijkende planning of in silico studie

Courtesy Hans Langendijk
In silico studies
Vertaling naar klinisch voordeel m.b.v. NTCP-model

Courtesy Hans Langendijk
Conclusions

• Toxicity is more than your gantry can cause
• Integral dose is largely dependent on machine and technique not on IMRT or not
• Patient data on IMRT sec. cancers are not mature yet
• Risk for sec. cancers is higher for younger patients
• A difference in radiation field can translate in less cancer (BC in HD disease)