Brachytherapy and particle therapy

CRISTER CEBERG
Types of radiotherapy

» External beam radiotherapy (teletherapy)
  – Cobalt unit
  – Linear accelerator (linac)
  – Particle beams

» Brachytherapy
  – Sealed sources (capsules, needles, ”seeds”)

» Radiopharmacological therapy
  – Non-sealed sources
Varian’s RapidArc technology
Particle radiotherapy

» External radiotherapy is also given with
  – Protons
  – Heavy ions
  – Neutrons
Alternative radiotherapy

Arlene Lennox, Fermilab, 2003
Protons

» Better geometric precision
Neutroner

» Higher biological effect

E.J. Hall, 1978
Linear energy transfer (LET)

Low-LET radiation
e.g. photons

High-LET radiation
e.g. neutrons
Relative biological effect (RBE)

Low-LET radiation
  e.g. photons

High-LET radiation
  e.g. neutrons
Precision vs. effectiveness

- Neutrons
- X-rays
- Linac
- Protons

E.J. Hall, 1978
Precision and effectiveness?

E.J. Hall, 1978
Proton radiotherapy
Improved conformity

Photon plan

Proton plan
Spot scanning
Proton gantry

Diameter ca 10 m, weight ca 120 ton
Proton gantry

Durchmesser: 13 m
Länge: 25 m
Gewicht: 600 Tonnen
Davon bewegt: 420 Tonnen
Max. Deformation: 0.5 mm
The Skandion clinic
Neutron radiotherapy

- Robert Stone started clinical trials at Berkely in 1938
- After WWII, Mary Catterall restarted clinical trials at Hammersmith in 1965
- Neutron therapy may improve local control
- It was realized that high energies are required (>30 MeV)
Orleans
Fixed horizontal beam at Fermilab
Isocentric gantry in Faure
MLC in Faure
Isocentric gantry in Detroit
Depth dose curves
Treatment plan (Faure)
Neutrons vs. photons

» Higher LET

» RBE about 3

» Less oxygen effect

» Less cell-cycle effect
Clinical implications

» Radioresistant tumours

» Large, poorly oxygenated tumours

» Slowly growing tumours with a small fraction of cells in mitosis

» Less reason for fractionation may lead to shorter treatment times

» Possibly useful for salivary gland neoplasms and for prostate cancer
Conclusion

» Previous lack of understanding lead to inappropriate use of neutron therapy
  – Dosimetry
  – Difference in radiation sensitivity

» Some patient may benefit from neutron radiotherapy
  – Predictive assays are needed
## Neutron radiotherapy facilities

<table>
<thead>
<tr>
<th>Centre</th>
<th>Country</th>
<th>Neutron source</th>
<th>Patients treated</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRM II Munich</td>
<td>Germany</td>
<td>Reactor</td>
<td>80</td>
<td>2 treatment rooms (one vertical and one horizontal beam). No multi-leaf collimator</td>
</tr>
<tr>
<td>Snezhinsk</td>
<td>Russia</td>
<td></td>
<td>990</td>
<td></td>
</tr>
<tr>
<td>Tomsk</td>
<td>Russia</td>
<td></td>
<td>1,200</td>
<td></td>
</tr>
<tr>
<td>iThemba Labs</td>
<td>South Africa</td>
<td>Separated Sector Cyclotron, 66MeV p+ on a Be target</td>
<td>1,700</td>
<td>Isocentric unit with Multi-blade trimmer.</td>
</tr>
<tr>
<td>Detroit</td>
<td>USA</td>
<td>Cyclotron d(48.5)+Be</td>
<td>2,200</td>
<td></td>
</tr>
<tr>
<td>Fermilab</td>
<td>USA</td>
<td>Proton Linear Accelerator ~70MeV</td>
<td>3,000+</td>
<td>Currently some 30-40 patients annually</td>
</tr>
<tr>
<td>Seattle</td>
<td>USA</td>
<td>Cyclotron 50 MeV</td>
<td>2,750</td>
<td></td>
</tr>
</tbody>
</table>

http://www.neutrontherapy.com/
Brachytherapy

» Intracavitary
  – Gynaecological cancer
  – Nasopharynx
  – Endoluminal treatments

» Interstitial
  – Head-and-neck tumours
  – Anal cancer
  – Prostate cancer
  – Breast cancer

» Surface applicators
  – Eye melanoma
Brachytherapy

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half-life</th>
<th>Energy (MeV)</th>
<th>Clinical use</th>
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</thead>
<tbody>
<tr>
<td>137Cs</td>
<td>30 y</td>
<td>0.66 (γ)</td>
<td>LDR interstitial and intracavitary</td>
</tr>
<tr>
<td>60Co</td>
<td>5.3 y</td>
<td>1.25 (γ)</td>
<td>HDR intracavitary</td>
</tr>
<tr>
<td>192Ir</td>
<td>73.8 d</td>
<td>0.397 (γ)</td>
<td>LDR interstitial HDR interstitial and intracavitary</td>
</tr>
<tr>
<td>125I</td>
<td>60 d</td>
<td>0.028 (γ)</td>
<td>Permanent interstitial implants (“seeds”)</td>
</tr>
<tr>
<td>103Pd</td>
<td>17 d</td>
<td>0.02 (β)</td>
<td>Permanent interstitial implants (“seeds”)</td>
</tr>
<tr>
<td>32P</td>
<td>14.3 d</td>
<td>1.71 (β)</td>
<td>Surface applicator</td>
</tr>
</tbody>
</table>

LDR: 0.4 – 2.0 Gy/h
HDR: 1-2 Gy/min
HDR afterloader
HDR afterloader

Connects to applicator

Guide tube
Intracavitary applicator
Intracavitary applicator
Intracavitary applicator
Interstitial applicator
Interstitial applicator
Treatment delivery
Treatment delivery