Proton Treatment

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Proton Dose vs. Depth

History of Proton Beam Therapy

- Suggested by Robert R. Wilson in 1946
  - Modern accelerators have enough energy
- First proton treatment at Berkeley in 1954
- Treatment program at HCL from 1961 to 2002
  - Fixed beam
  - Energy: 160 MeV
  - Treated over 9000 patients
  - ~3000 for ocular disease
### Age Compared to Other Innovations

<table>
<thead>
<tr>
<th>Older Innovations</th>
<th>Younger Innovations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles</td>
<td>Hula Hoops</td>
</tr>
<tr>
<td>Airplanes</td>
<td>Cassette tapes</td>
</tr>
<tr>
<td>Electronic computers</td>
<td>BASIC computer language</td>
</tr>
<tr>
<td>Frisbee</td>
<td>Lasers</td>
</tr>
<tr>
<td>Velcro</td>
<td>CT scans</td>
</tr>
<tr>
<td>Radial tires</td>
<td>PET scans</td>
</tr>
</tbody>
</table>
Why use protons instead of photons for cancer therapy?

- Ability to treat tumors close to sensitive organs like the spinal cord
- Ability to re-treat tumors after recurrences
- Decreased risk of secondary cancers
  - Risk for some childhood cancers survivors is $\times 9$ normal
- Decreased dose to normal tissues $> 50$
  - Decreased risk of side-effects
  - Which increases ability to retreat
Getting the Protons

Cyclotron and degrader

Linear accelerator?

Laser acceleration?

Synchrotron
Getting beam to patient

- Want the beam direction from $360^\circ$ in (at least) one plane
- Gantry dimensions largely defined by proton bending radius and beam shaping equipment
- Can accomplish some of this by moving the patient
Distributing Radiation Throughout Tumor

- Passive scattering
  - Spread out Bragg peak (SOBP)
  - Scatterer and range modulator
  - Patient specific collimator or multileaf collimator
  - Used at HCL for its 41 years
  - Drawbacks: tumor conformity and neutrons
- Active targeting / pencil beam scanning
  - Direct pristine beam toward tumor location
  - Change energy or position and repeat
  - Drawback: complexity
Radiation Safety Advantages
(Why you should prefer proton treatments)

• Decrease in necessary beam current
  • The dose is deposited in the tumor, not the room
  • Linac ∼mA electron beam needed to make photons
  • Proton treatments need nA beams (more than makes up for E)
  • Caveat: passive scatter gives considerable neutron dose

• Some “beam making” is not in the vault
  • These are sources of radiation and activation
  • For linac, beam making is accelerator and head
  • For proton it is accelerator, degrader, and (maybe) scatterer
Treatment Dose Absorption

http://www.oncoprof.net/Generale2000/g08_Radiotherapie/Images/PicBragg.gif
## Radiation Levels in Proton Vault

(195 MeV Passively Scattered Beam, 0.6 Gy/min)

<table>
<thead>
<tr>
<th>Location</th>
<th>Photons (mR/hr)</th>
<th>Neutrons (mrem/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m from isocenter</td>
<td>28</td>
<td>1800</td>
</tr>
</tbody>
</table>

(Unfortunately no pencil scanning beam data yet)

## Approximate Radiation Levels in Linac Vault

(18 MV Beam, 0.6 Gy/min)$^\dagger$

<table>
<thead>
<tr>
<th>Location</th>
<th>Photons (mR/hr)</th>
<th>Neutrons (mrem/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m from isocenter</td>
<td>720</td>
<td>2000</td>
</tr>
</tbody>
</table>

Activation in the Treatment Room

- There is activation of the collimator, scatterer, etc.
- Activation can be reduced by choices of materials
- Radiation levels are reasonable and decay is rapid
- Again, the problem should be less with pencil beam scanning
Radiation Levels After 10 Minute Irradiation in Treatment Room (1 Meter from Nozzle)

Note: treatment times for beams are about a minute, so beam is on <4 min/hr
Doses and Activation near the Cyclotron

- Accelerators are often largely self-shielding
  - Dose rates where beam hits something
- Beam currents here much larger than in rooms
- Dose to workers from accelerator primarily from maintenance work
- The energy degrader is an issue
  - Here the beam hits something
  - But it is not near the patients (or anybody)
Radiation Level Variation With Proton Beam Energy (Center of Walkway*)

<table>
<thead>
<tr>
<th></th>
<th>Dose Rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>210 MeV proton beam</td>
<td>3200 mR/hr 7000 mR/hr</td>
</tr>
<tr>
<td>100 MeV proton beam</td>
<td>photon</td>
</tr>
<tr>
<td>7.2 mrad/hr</td>
<td>neutron</td>
</tr>
<tr>
<td>1140 mrad/hr</td>
<td>8 feet from degrader</td>
</tr>
</tbody>
</table>

*8 feet from degrader
Mechanism to ensure these areas are clear is necessary
Safety Systems - Zones

- Gates to separate zones in vault
- Interlocked
- Only search zones when interlock is tripped
Radiation Levels in Vault Immediately After 10 Minute Irradiation

<table>
<thead>
<tr>
<th>Area</th>
<th>mR/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m degrader</td>
<td>60</td>
</tr>
<tr>
<td>Area A</td>
<td>4</td>
</tr>
<tr>
<td>Area B</td>
<td>16</td>
</tr>
<tr>
<td>Area C</td>
<td>4</td>
</tr>
<tr>
<td>Area D</td>
<td>2.6</td>
</tr>
</tbody>
</table>
Radiation Levels After 10 Minute Irradiation in Vault (1 meter from Degrader)

Radiation Level vs. Time for Activation Products

Minutes After Irradiation

mR/hr
Summary

• Proton treatment is a new medical modality just like CT imaging and PET imaging
  • Remember, “There is no reason for any individual to have a computer in his home.” (Much less his pocket)

• The Bragg peak means “all” the energy goes to the tumor
  • Less stray radiation
  • Less secondary cancers
The End

Questions?
Facility Layout
Proton Facility Layout

- Entrance maze
- Cyclotron
- Gantry #1
- Beam line
- Research Area