Proton therapy: past, present and future
Terapia con protoni: Passato, presente e futuro

Tony Lomax, Centre for Proton Radiotherapy,
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Overview

1. The past: passive scattering
2. The present: spot scanning and IMPT
3. The future: dealing with uncertainties
The past: passive scattering

Extending the dose in depth – the ‘Spread-out-Bragg-peak’
Proton treatment delivery

Making protons useful 1. Passive scattering in practice

Collimator

Compensator

Range-shifter wheel

Scatterer

Target

Patient
The past: passive scattering

Single passively scattered field

Three passively scattered fields

Fixed extent SOBP leads to poor sparing of normal tissue proximal to target

Conformation of dose can be improved through the use of multiple fields
The past: passive scattering

50 years of proton therapy.

Nearly 50,000 patients treated in 27 centres world-wide.

<table>
<thead>
<tr>
<th>Location</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lawrence Berkeley Laboratory (USA) 1954-1992</td>
<td>&gt;2500</td>
</tr>
<tr>
<td>Los Alamos (USA) 1974-1982</td>
<td>&gt;230</td>
</tr>
<tr>
<td>Harvard/MGH (USA)</td>
<td>&gt;11000</td>
</tr>
<tr>
<td>Loma Linda (USA)</td>
<td>&gt;10000</td>
</tr>
<tr>
<td>Nice, Orsay (France)</td>
<td>&gt;5600</td>
</tr>
<tr>
<td>Dubna, Moskau, St. Petersburg (Russia)</td>
<td>&gt;5200</td>
</tr>
<tr>
<td>Chiba, Tsukuba, Hyogo, Kashiwa, Shizuoca (Japan)</td>
<td>&gt;4900</td>
</tr>
<tr>
<td>PSI (Switzerland)</td>
<td>&gt;4400</td>
</tr>
<tr>
<td>Clatterbridge (UK)</td>
<td>&gt;1300</td>
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<tr>
<td>San Francisco, Bloomington (USA)</td>
<td>&gt;680</td>
</tr>
<tr>
<td>Berlin since 1999, Catania (Sicily) since 2000</td>
<td>&gt;680</td>
</tr>
<tr>
<td>South Africa</td>
<td>&gt;470</td>
</tr>
<tr>
<td>Uppsala (Sweden)</td>
<td>&gt;400</td>
</tr>
<tr>
<td>GSI Darmstadt (Germany)</td>
<td>&gt;190</td>
</tr>
<tr>
<td>Wanji (China)</td>
<td>&gt;30</td>
</tr>
</tbody>
</table>
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The present: spot scanning and IMPT

Spot scanning

Proton pencil beam

Magnetic scanner

‘Range shifter’ plate

Target

Patient

The present: spot scanning and IMPT

Selected spots

Initial dose distribution

Dose calculation

Optimised dose

Spot weight optimisation

Dose Calculation

Scheib, ETH Diss 10451, 1993

protons useful
Spot scanning in practice

Spot definition

Initial dose distribution

Dose calculation

Optimised dose

Spot weight optimisation

Dose Calculation

Scheib, ETH Diss 10451, 1993

The present: spot scanning and IMPT

Selected spots

Initial dose distribution

Dose calculation

Optimised dose

Spot weight optimisation

Dose Calculation

Scheib, ETH Diss 10451, 1993
A spot scanned plan consists of the addition of one or more individually optimised fields.

Note, each individual field is homogenous across the target volume.
Intensity Modulated Proton Therapy: The simultaneous optimisation of all Bragg peaks from all incident beams. E.g.,

The present: spot scanning and IMPT

The three ‘orders’ of proton therapy compared
Between 1996 and end of 2005, 262 patients have been treated using scanned protons at PSI (+18 in 2007).
Case 1. A sarcoma in a 12 year old boy

Delivered single field plan

9 field IMRT plan

Factor 6 lower integral dose for protons
Between 1999 and 2004, 43 of a total of 209 patients have been treated with IMPT as part of their full proton treatment.

Mean number of series (plans) per patient: 2.6
Mean number of IMPT series per (IMPT) patient: 1.3
Mean number of fields per IMPT plan: 3.3
The present: spot scanning and IMPT

Two examples of clinical IMPT plans delivered at PSI

Sacral chordoma, 10 year old girl

Skull-base chordoma

3 fields

4 fields
Manufacturers currently offering photon therapy equipment

- Varian
- Elekta
- Siemens

Manufacturers currently offering particle therapy equipment

- Optivus (p)
- Mitsubishi (p)
- Ion Beam Applications (p,s)
- Hitachi (p,s)
- Varian/Accell (s)
- Siemens (s)

The present: spot scanning and IMPT

Industrial suppliers of radiotherapy equipment
Overview

1. The past: passive scattering
2. The present: spot scanning and IMPT
3. The future: dealing with uncertainties? (and the ‘Milano’ connection)
The advantage of protons is that they stop.

The disadvantage of protons is that we don’t always know where…

10% range error
The future: dealing with uncertainties

3 field IMPT plan to an 8 year old boy

During treatment, 1.5kg weight gain was observed

Note, sparing of spinal cord in middle of PTV

Max range differences:
- SC 0.8cm
- CTV 1.5cm

The ‘Milano’ connection: Alessandra Bolsi and Francesca Albertini
The future: dealing with uncertainties

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Automatic adaptation of Bragg peak ranges on a spot by spot basis depending on local change in range

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Tony Lomax, La Fisica Medica in Lombardia, May 23rd 2007
The future: dealing with uncertainties

kV-CT

Accuracy of range calculation due to reconstruction artifacts?

MV-CT (tomotherapy)

No artifacts and linear relationship CT units to proton stopping power

The ‘Milano’ connection:
Francesca Albertini and Ospedale San Raffaele

Ospedale San Raffaele, Milan

Tony Lomax, La Fisica Medica in Lombardia, May 23rd 2007
The "Milano" connection:
Francesca Albertini and Ospedale San Rafaele

The future: dealing with uncertainties

Stopping power profiles

kV-CT artifacts

Prosthesis
Summary

- Proton therapy is a mature technique, with more than 50,000 patients treated worldwide.
- Spot scanning/IMPT provides improved flexibility and conformality in comparison to passive scattering.
- Protons are coming of age – many new facilities being built and planned, most will provide scanning capability.
- However, protons bring their own challenges – e.g. detecting and dealing with range uncertainties.
- We’re investigating this with the help of medical physicist trained in Lombardy…
Grazie!