Comparison of Optimal Photon and Proton Therapy Planning

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RBE vs LET

Raju, IJRB, 67, 237, 1995

LET (keV/μm)

RBE
Acta Oncologica, 44(8), 2005; Special issue on proton beam

**ORIGINAL ARTICLE**

- **The potential of proton beam radiation therapy in intracranial and ocular tumours**
  - Authors: Erik Blomquist; Göran Bjelkengren; Bengt Glimelius
  - DOI: 10.1080/02841860500355934
  - Pages: 862 – 870

- **The potential of proton beam therapy in paediatric cancer**
  - Authors: Thomas Björk-Eriksson; Bengt Glimelius
  - DOI: 10.1080/02841860500355959
  - Pages: 871 – 875

- **The potential of proton beam radiation therapy in head and neck cancer**
  - Authors: Anders Ask; Thomas Björk-Eriksson; Björn Zackrisson; Erik Blomquist; Bengt Glimelius
  - DOI: 10.1080/02841860500355991
  - Pages: 876 – 880

- **The potential of proton beam radiation therapy in lung cancer (including mesothelioma)**
  - Authors: Göran Bjelkengren; Bengt Glimelius
  - DOI: 10.1080/02841860500355975
  - Pages: 881 – 883

- **The potential of proton beam radiation therapy in breast cancer**
  - Authors: Thomas Björk-Eriksson; Bengt Glimelius
  - DOI: 10.1080/02841860500355918
  - Pages: 884 – 889

- **The potential of proton beam radiation therapy in prostate cancer, other urological cancers and gynaecological cancers**
  - Authors: Bengt Johansson; Mona Ridderheim; Bengt Glimelius
  - DOI: 10.1080/02841860500355942
  - Pages: 890 – 895

- **The potential of proton beam radiation therapy in gastrointestinal cancer**
  - Authors: Anders Ask; Bengt Johansson; Bengt Glimelius
  - DOI: 10.1080/02841860500355926
  - Pages: 896 – 903

- **Adjuvant chemotherapy in colorectal cancer: A joint analysis of randomised trials by the Nordic Gastrointestinal Tumour Adjuvant Therapy Group**
  - Authors: Bengt Glimelius; Olav Dahl; Björn Cedermark; Anders Jakobsen; Søren M. Bentzen; Hans Starkhammar; Henrik Grönberg; Ragnar Hultborn; Maria Albertsson; Lars Påhlman; Kjell-Magne Tveit
  - DOI: 10.1080/02841860500355900
  - Pages: 904 – 912

- **The potentials of proton beam radiation therapy in malignant lymphoma, thymoma and sarcoma**
  - Authors: Thomas Björk-Eriksson; Göran Bjelkengren; Bengt Glimelius
  - DOI: 10.1080/02841860500355983
  - Pages: 913 – 917

- **The potential of proton beam radiation for palliation and reirradiation**
  - Authors: Thomas Björk-Eriksson; Anders Ask; Bengt Glimelius
  - DOI: 10.1080/02841860500355967
  - Pages: 918 – 920
Tumor Type & Radiation Selection

Ill Defined Boundary

Well Defined Boundary

Photon

Proton

ID/AAPM/09
SOBP Redistribution
IMRT Plan of head and neck nodes

Spillage & background radiation

Dose (cGy) = 6501.38
Variations in doses in 803 patients among institutions

Das et al. J Natl Cancer Inst 100 (5), 300-3007, 2008  ID/AAPM/09
Proton beam, Post Fossae Tumor
Proton beam, Chordomo, Reirradiation
Proton, different beam arrangements
Meningioma, Proton Beam

30%-100%
SBRT, Lung

Photon

Proton
## Results of the SBRT

### Whole Lung Dose

<table>
<thead>
<tr>
<th></th>
<th>SBRT</th>
<th>SBPT</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Dose</td>
<td>116.7%</td>
<td>104.3%</td>
<td>-9.7% (+133 to -15.6%)</td>
</tr>
<tr>
<td>Mean Dose</td>
<td>9.3%</td>
<td>2.1%</td>
<td>-64.9% (-30.4 to -98.4%)</td>
</tr>
<tr>
<td>$V_{50%}$</td>
<td>99.4 cm$^3$</td>
<td>53.5 cm$^3$</td>
<td>-45.8 cm$^3$ (0 to -248 cm$^3$)</td>
</tr>
</tbody>
</table>
## Results of the SBRT

### Body Dose

<table>
<thead>
<tr>
<th></th>
<th>SBRT</th>
<th>SBPT</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Dose</td>
<td>125.3%</td>
<td>107.3%</td>
<td>-14.0% (-9 to -17%)</td>
</tr>
<tr>
<td>Mean Dose</td>
<td>2.5%</td>
<td>0.7%</td>
<td>-68.9% (-51 to -80%)</td>
</tr>
<tr>
<td>(V_{50%})</td>
<td>224.8 cm(^3)</td>
<td>195.4 cm(^3)</td>
<td>-38.6 cm(^3) (0 to -238 cm(^3))</td>
</tr>
</tbody>
</table>
Muzik, Soukup, Alber, Med Phys, 35, 1580, 2008
Partial Breast Irradiation

Photon  Electron  Proton
Muzik, Soukup, Alber, Med Phys, 35, 1580, 2008
Retreatment; Proton Patch & Match fields
RESULTS OF SPOT-SCANNING PROTON RADIATION THERAPY FOR CHORDOMA AND CHONDROSARCOMA OF THE SKULL BASE: THE PAUL SCHERRER INSTITUTE EXPERIENCE

Damien C. Weber, M.D.,* † Hans Peter Rutz, M.D.,* Eros S. Pedroni, Ph.D.,* Alessandra Bolsi, M.Sc.,* Beate Timmermann, M.D.,* Jorn Verwey, M.Sc.,* Antony J. Lomax, Ph.D.,* and Gudrun Goitein, M.D.*

*Department of Radiation Medicine, Proton Therapy Program, Paul Scherrer Institut, Villigen, Switzerland; †Department of Radiation Oncology, Geneva University Hospital, Geneva, Switzerland
Systematic review

A systematic literature review of the clinical and cost-effectiveness of hadron therapy in cancer

Mark Lodgea,*, Madelon Pijls-Johannesmab, Lisa Stirkc, Alastair J. Munrod, Dirk De Ruysschere, Tom Jeffersona

aCochrane Cancer Network, Oxford, UK, bMAASTRO Clinic, Maastricht, The Netherlands, cCentre for Reviews & Dissemination, University of York, UK, dUniversity of Dundee, Scotland, UK, eUniversity Hospital Maastricht, GROW, MAASTRO Clinic, Maastricht, The Netherlands

Conclusion: Existing data do not suggest that the rapid expansion of HT as a major treatment modality would be appropriate. Further research into the clinical and cost-effectiveness of HT is needed. The formation of a European Hadron Therapy Register would offer a straightforward way of accelerating the rate at which we obtain high-quality evidence that could be used in assessing the role of HT in the management of cancer.

Results: Seven hundred and seventy three papers were identified. For proton and heavy ion therapy, the number of RCTs was too small to draw firm conclusions. Based on prospective and retrospective studies, proton irradiation emerges as the treatment of choice for some ocular and skull base tumours. For prostate cancer, the results were comparable with those from the best photon therapy series. Heavy ion therapy is still in an experimental phase.

Conclusion: Existing data do not suggest that the rapid expansion of HT as a major treatment modality would be appropriate. Further research into the clinical and cost-effectiveness of HT is needed. The formation of a European Hadron Therapy Register would offer a straightforward way of accelerating the rate at which we obtain high-quality evidence that could be used in assessing the role of HT in the management of cancer.

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Systematic review

Proton therapy — A systematic review of clinical effectiveness

Dag Rune Olsen\textsuperscript{a, b, c}, Øyvind S. Bruland\textsuperscript{a, b}, Gunilla Frykholm\textsuperscript{c}, Inger Natvig Norderhaug\textsuperscript{d}

\textsuperscript{a}Rikshospitalet-Radiumhospitalet Medical Center, Oslo, Norway, \textsuperscript{b}University of Oslo, Norway, \textsuperscript{c}St. Olavs Hospital, Trondheim, Norway, \textsuperscript{d}Norwegian Knowledge Centre for the Health Services, Oslo, Norway

Conclusion: The evidence on clinical efficacy of proton therapy relies to a large extent on non-controlled studies, and thus is associated with low level of evidence according to standard health technology assessment and evidence based medicine criteria.

Materials and methods: A systematic review of published studies that investigated clinical efficacy of proton therapy of cancer.

Results: We included 54 publications: 4 randomized controlled trials (RCTs) reported in 5 publications, 5 comparative studies and 44 case series. Two RCTs addressed proton irradiation as a boost following conventional radiation therapy for prostate cancer, where one demonstrated improved biochemical local control for the highest dose group without increased serious complication rates. Proton therapy has been used to treat a large number of patients with ocular tumours, but except for one low quality RCT, no proper comparison with other treatment alternatives has been undertaken. Proton therapy offers the option to deliver higher radiation doses and/or better confinement of the treatment of intracranial tumours in children and adults, but reported studies are heterogeneous in design and do not allow for strict conclusions.

Conclusion: The evidence on clinical efficacy of proton therapy relies to a large extent on non-controlled studies, and thus is associated with low level of evidence according to standard health technology assessment and evidence based medicine criteria.

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\textit{Keywords:} Systematic review; Proton therapy; Clinical effectiveness
Conclusions

- Protons & heavy ion do provide physical and biological dose advantage over photon and electrons
- Protons achieve substantial dose reductions to most OAR and to the whole body relative to Photon treatment in most cases
- Proton provides better quality of life by reducing dose to normal tissues
- Integral dose in PT is much lower compared to photon beam and hence possible reduction in secondary malignancies that have a latent period of 10-20 yrs
- Suitable for inoperable, complex and previously treated areas
-Conclusions

- Each technique excels for certain classes of highly complex cases
- Radiation treatment modalities should be viewed as complementary, rather than competing
- Financially these are extremely expensive and will be limited to developed and rich countries only
- Clinical advantage thus far is shown only in solid brain tumors
- Additional research in technology, cost and clinical outcome is needed
Acknowledgement

Peter A.S. Johnstone, MD, FACR

MPRI staff