Overview of pediatric Radiotherapy: photon, proton, and beyond

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1/3 children with cancer treated with radiation therapy

84% of children with cancer now survive 5 years or more (American Cancer Society)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>% of childhood cancers</th>
<th>5-year survival rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNS tumors</td>
<td>26%</td>
<td>76% (20% in glioblastoma multiforme, 2% in diffuse intrinsic pontine glioma)</td>
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<tr>
<td>Medulloblastoma, ependymoma, optic nerve glioma, pilocytic astrocytoma, craniopharyngioma, germ cell tumor, ganglioglioma, brainstem glioma, glioblastoma</td>
<td>26%</td>
<td>76% (20% in glioblastoma multiforme, 2% in diffuse intrinsic pontine glioma)</td>
</tr>
<tr>
<td>Retinoblastoma (eye cancer)</td>
<td>2%</td>
<td>96%</td>
</tr>
<tr>
<td>Hodgkin and non-Hodgkin lymphoma</td>
<td>11%</td>
<td>98% and 90%</td>
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<tr>
<td>Neuroblastoma</td>
<td>4%</td>
<td>80%</td>
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<tr>
<td>Wilms tumor</td>
<td>6%</td>
<td>96%</td>
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<tr>
<td>Rhabdomyosarcoma (orbit, H&amp;N, cranial parameningeal, GU bladder/prostate, extremity, trunk)</td>
<td>2%</td>
<td>79%</td>
</tr>
<tr>
<td>Bone cancer (Osteosarcoma, Ewing sarcoma)</td>
<td>5%</td>
<td>72%</td>
</tr>
<tr>
<td>Leukemia</td>
<td>25%</td>
<td>90% (acute lymphocytic leukemia)</td>
</tr>
</tbody>
</table>

Data from American Cancer society, NCI, CURESEARCH.org, DIPG.org
Late effects from pediatric radiation therapy

Long-term effects seen in childhood cancer survivors treated in 1950-2000 (pre 3DCRT/IMRT) raised significant awareness.

Late effects may include
- neurocognitive and learning problems
- hearing loss
- vision/cataract
- dental problems
- endocrine dysfunction
- cardiovascular disease
- pulmonary dysfunction
- growth retardation and skeletal deformity
- Infertility
- secondary malignancy

Trends continue to reduce total dose, eliminate RT for early stage patients, and apply highly conformal techniques.

Efforts in reducing toxicity seem to be working but more work need to be done.
Treatment modalities for pediatric radiotherapy

**Linear accelerator-based therapy** since 1953

First proton beam treatment in 1954

**Contemporary Linac photon**

**Carbon ion therapy** for skull based tumors and osteosarcoma

Brachytherapy for retinoblastoma and sarcoma

**MR guided RT** for sarcoma

SRS less common; SBRT for bone tumors
Photon therapy is currently the most common RT modality in pediatric cancer.

Hua et al. Pediatric Blood Cancer 2020
Access to proton therapy could be an issue

2017 Children’s Oncology Group survey showed only 20% of pediatric radiation oncologists have access to proton therapy.

There are ~2100 radiation oncology sites in US but only 31 operational proton centers.

The median number of pediatric patients per proton center in a year was 29 (Journy et al, Radiother Oncol 2019).

Estimated 1 in 5 pediatric radiation treatments in US is delivered with proton beams (15,780 children with cancer each year in US; 1/3 receives RT; assuming 1,000 children treated with protons annually).

We don’t have the capacity yet to treat all pediatric patients at proton centers. But new proton centers are being built every year.
Treatment techniques for pediatric radiotherapy

Evolution from high dose, large fields to lower dose, conformal treatments (e.g. Hodgkin’s lymphoma)

Still have whole brain, whole lung, whole abdomen RT, and TBI for selected diseases. But IMRT/VMAT and protons are being utilized to spare OARs.

Intensity-modulated proton CSI to spare organs anterior to spine

Hall et al. Pediatric Hodgkin Lymphoma 2020, p277-296

Hua et al. Pediatr Blood Cancer 2020, in press
Questions remain

If we don’t treat most pediatric cancers with protons, are we not offering the best treatment?

How do you know the photon or proton plan is as good as it can be?

How would you advise if the child of your good friend needs radiation therapy?

Should we proceed slowly with caution or is it time to embrace the protons?
What can we do as medical physicists?

Many non-technical factors decide the treatment modality for a child with cancer – e.g., clinical evidence, reimbursement (ability to pay), access to proton facility, ability of caregiver and child to travel to another city for treatment, physician’s referral preference.

However, we should control what we can control.

- Keep up with technology advances
- Optimize its clinical applications
- Understand achievable and limitations of each RT modality
- Be able to offer the best care with your available technology for children that come to your center
- Be able to offer technical advice to clinicians when choosing treatment modalities
- Ready to implement new technologies when the time comes

Through point/counterpoint, we hope to stimulate discussions and raise the awareness of childhood cancer in the medical physics community.