



**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)



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

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

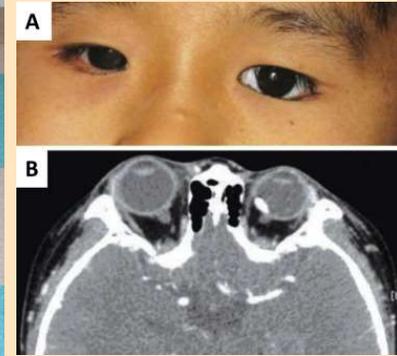
- neurocognitive and learning problems
- hearing loss
- vision/cataract
- dental problems
- endocrine dysfunction
- cardiovascular disease
- pulmonary dysfunction
- growth retardation and skeletal deformity
- Infertility
- secondary malignancy

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.



Krasin et al. Semin Radiat Oncol 2010



Choi et al. J Korean Med Sci 2010

BMJ 2020;368:m58 doi: 10.1136/bmj.m58 (Published 15 January 2020) Page 1 of 2

EDITORIALS

Falling risk of heart disease among survivors of childhood cancer

Efforts to reduce the cardiotoxicity of treatments seem to be working

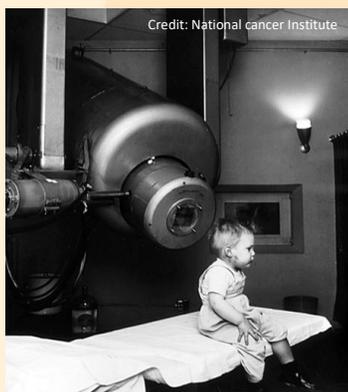
Mike Hawkins *chair in epidemiology*¹, Alex Brownsdon *clinical nurse specialist*², Raoul Reulen *senior lecturer*¹

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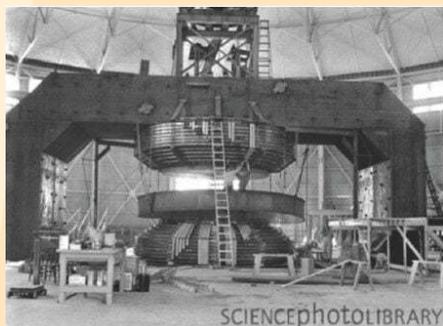


Treatment modalities for pediatric radiotherapy

Linear accelerator-based therapy since 1953



First proton beam treatment in 1954



Contemporary Linac photon



Contemporary proton

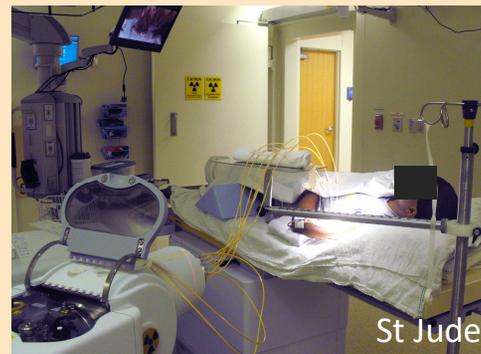


Carbon ion therapy for skull based tumors and osteosarcoma

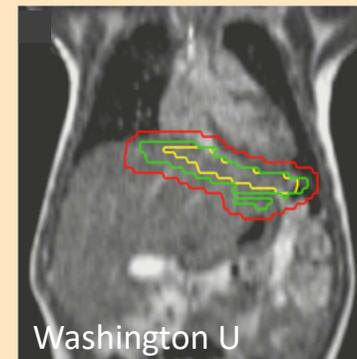


Mohamad et al. Cancers 2018

Brachytherapy for retinoblastoma and sarcoma



MR guided RT for sarcoma

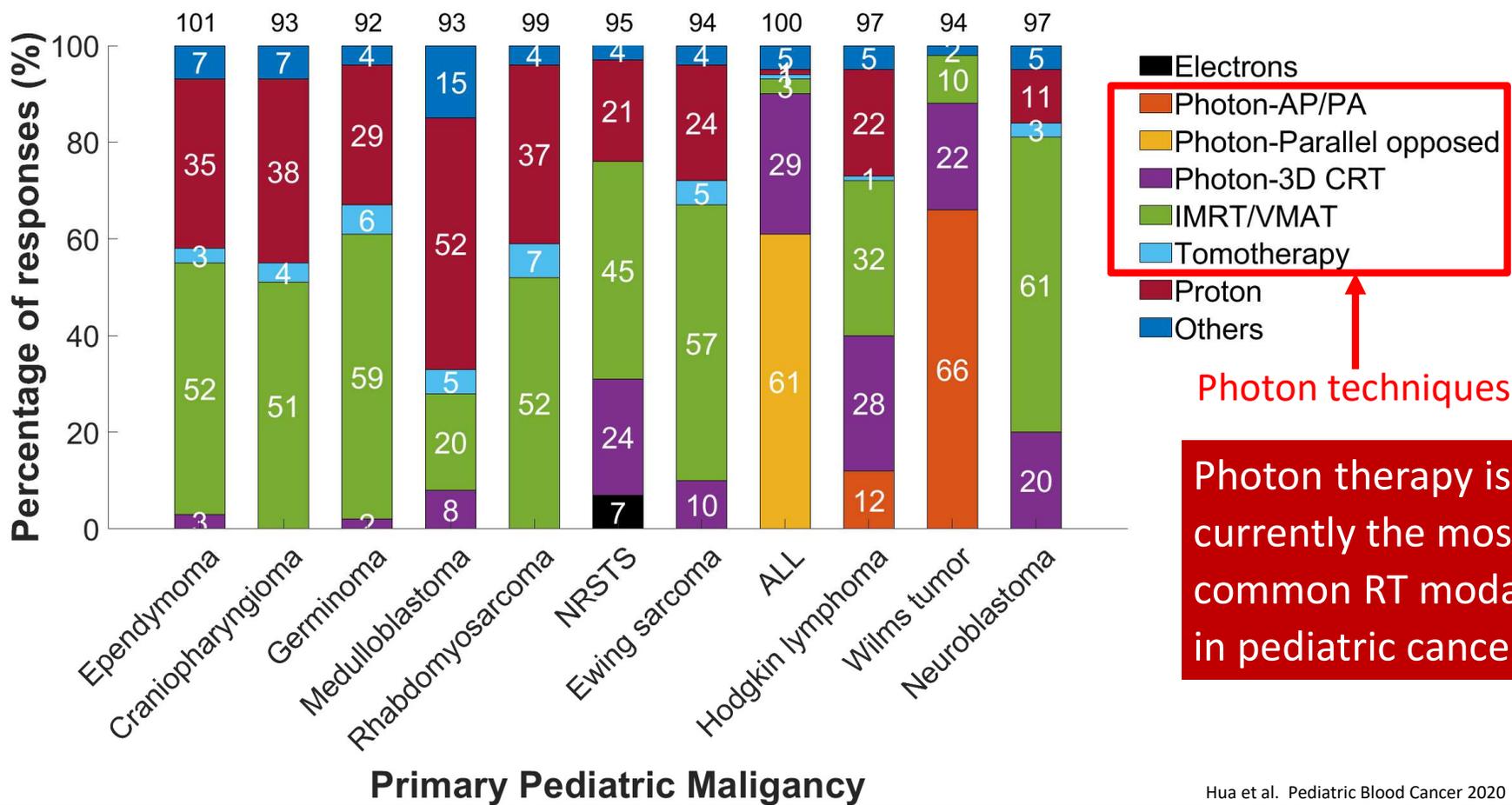


Henke et al. Adv Radiat Oncol 2019

SRS less common; SBRT for bone tumors



COG survey for pediatric radiotherapy modality use



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).

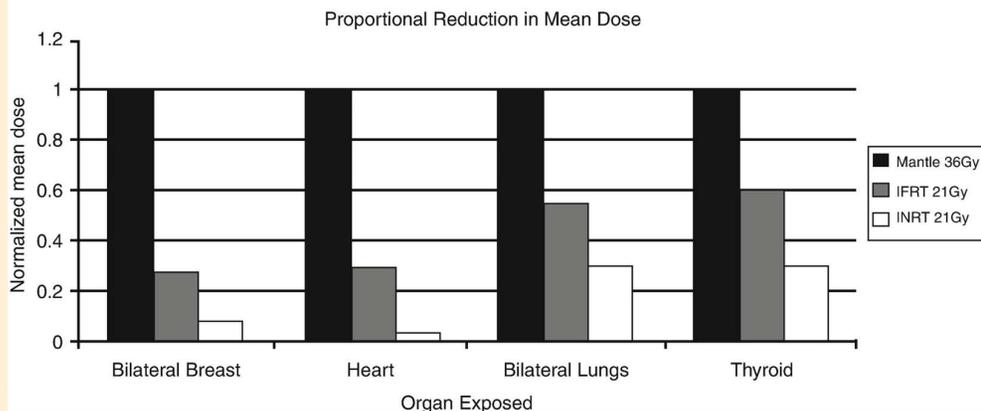
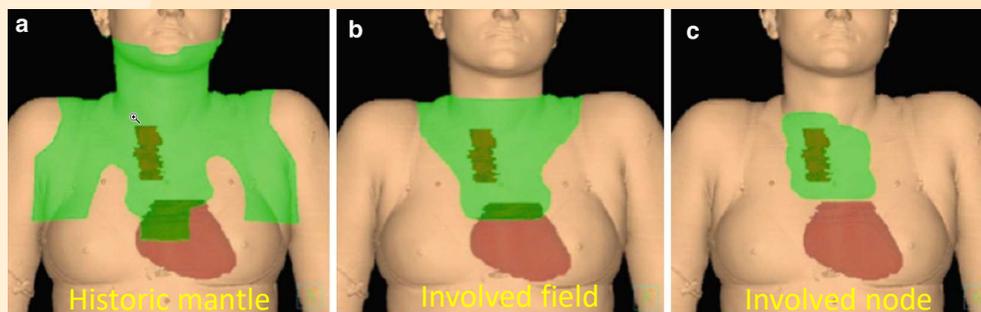
Estimated 1 in 5 pediatric radiation treatments in US is delivered with proton beams (15,780 children with cancer each year in US; 1/3 receives RT; assuming 1,000 children treated with protons annually).

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

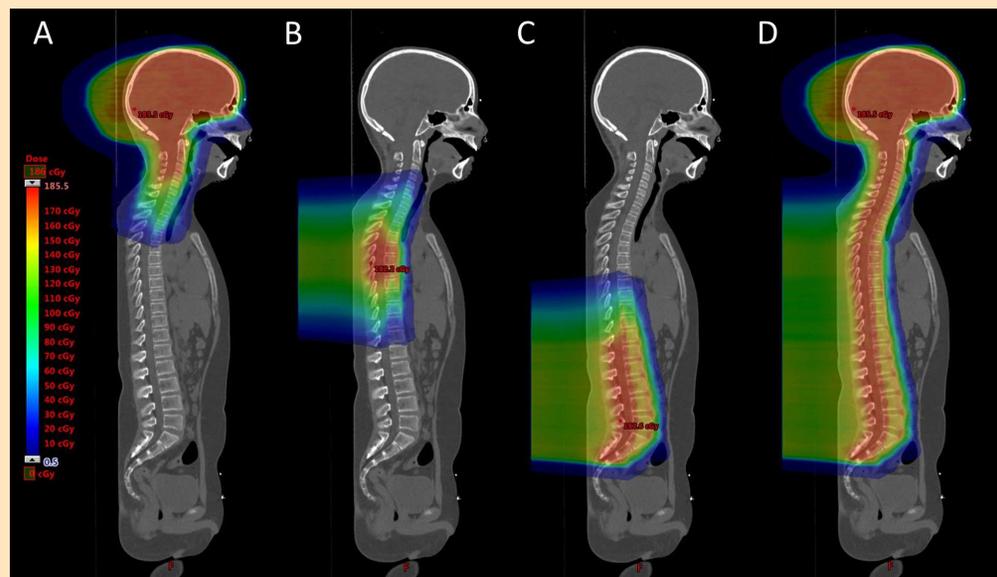
Evolution from high dose, large fields to lower dose, conformal treatments (e.g. Hodgkin's lymphoma)



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

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



Hua et al. Pediatr Blood Cancer 2020, in press



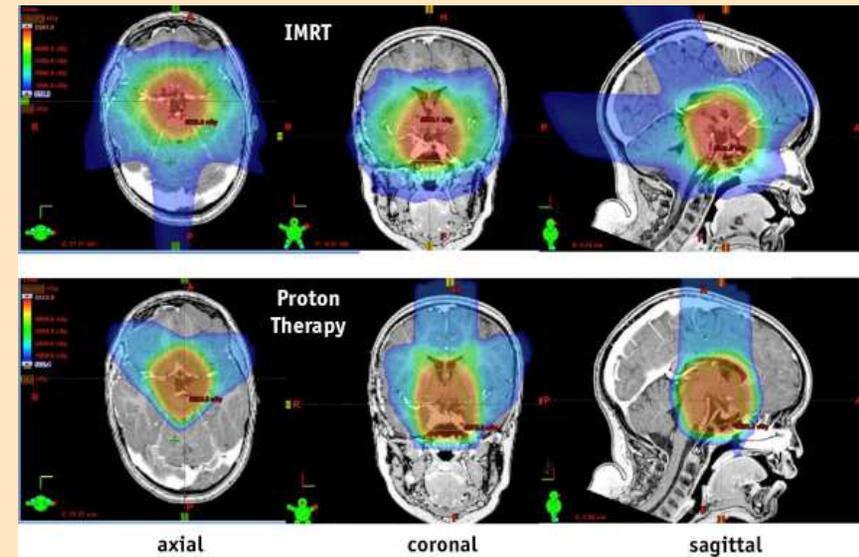
Questions remain

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.

