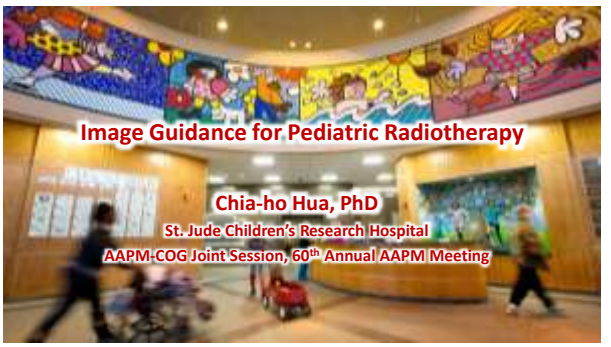


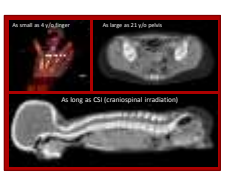
Outline

- Challenges of pediatric IGRT
- IGRT practice patterns for adults and children
- COG survey of pediatric IGRT practice
- Estimated doses to children from IGRT procedures
- Should we worry about the effect of image guidance dose?
- Strategies of reducing image guidance doses
- Summary

Challenges of pediatric RT and image guidance

Radiation sensitive structures adjacent to tumor and shorter distance in between than adults

Lens, optic chiasm, brainstem, cochlea, ovary, testis



Variation in body size requiring different imaging protocol settings

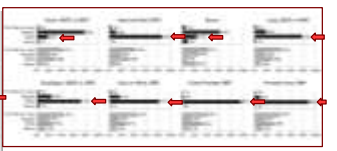
Previously reported IGRT practice patterns

Adults
- Australia and New Zealand 2008 (Rybovic et al., J Med Imaging Radiat Oncol, 52(2):183-190)
- ASTRO member survey 2016 (Nabavizadeh et al., IJROBP, 94(4):850-857)

Children
- Portal imaging practice of COG institutions 2008 (Olch et al, IJROBP, 67(2):594-600)
- Canadian pediatric imaging practice 2014 (Rodgerson, Radiography, 20(3):183-188)
- International Pediatric Research Consortium 2014 (Alcorn et al, Prac Radiat Oncol, 4(5):336-341)

Adult IGRT practice patterns

ASTRO survey 2016

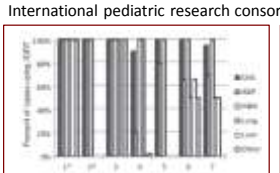


Volumetric imaging was common (60-77%) for all sites except breast.

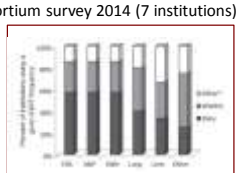
Daily IGRT was preferred for H&N, lung, prostate, esophagus, pelvis while weekly IGRT was popular for brain and breast.

Pediatric IGRT practice patterns

International pediatric research consortium survey 2014 (7 institutions)



IGRT was consistently employed in nearly all CNS cases but varied across facilities in abdominal and pelvic cases.



In contrast to adults, daily IGRT was performed more than weekly for CNS tumors.

Only 57% of photon institutions used specialized lower-dose pediatric protocols.

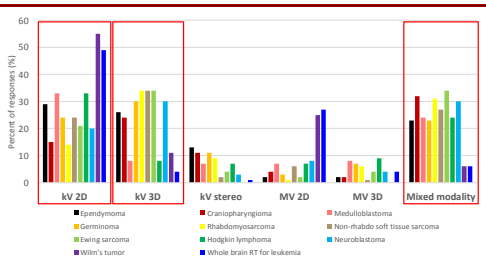
COG survey – design and response

Survey conducted in late 2017

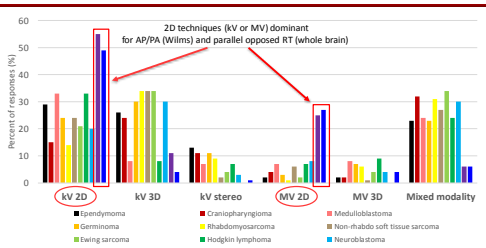
39 clinical questions designed for pediatric radiation oncologists (COG members)
23 technical questions for medical physicists

Responses from 105 radiation oncologists and 63 medical physicists

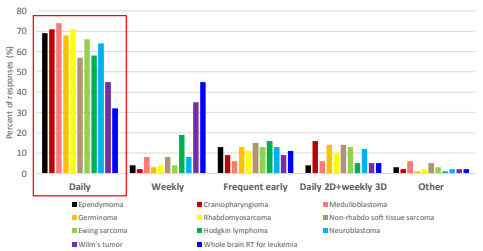
COG survey – recommended pediatric IGRT method



COG survey – recommended pediatric IGRT method

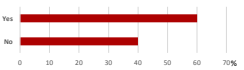


COG survey – recommended image guidance frequency

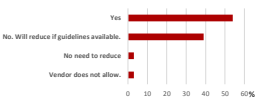


COG survey – selected results of technical questions

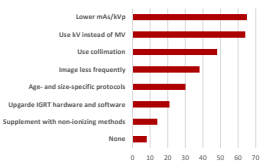
Q: Are anatomic site specific IGRT protocols used routinely for children?



Q: Does you institution modify kV/mAs setting from vendor's adult IGRT protocols for children?



Q: What measures are employed to reduce image guidance doses to pediatric patients (check all that apply)?



COG IGRT survey – Opinions

COG IGRT survey – Opinions

COG IGRT survey – Opinions

Estimated organ doses from IGRT procedures

Organ dose from CBCT depends on protocol setting (kVp, mAs, # projections, gantry start-stop angles), hardware, collimation (scan length), and child body habitus.

High quality head protocol
(Varian OBI, 80mA, 25ms, 204°, full bowtie filter)
4 y/o

OAR/mGy	60 kVp	80 kVp	100 kVp	125 kVp
Spinal cord	25	44	66	98
Brain	18	33	51	77
Eyes	9	16	24	38
Lens	11	16	23	35
Optic nerves	8	17	27	47

Deng J, et al. Int J Radiat Oncol Biol Phys 2012

High quality, standard, low-dose head protocols
(Varian OBI v1.4, 100kVp, 80mA/20mA/10mA, 20ms, 200°, full bowtie filter)
5 y/o

OAR/mGy	High quality head	Standard head	Low dose head
Brain	7.9	1.5	0.8
R/L eye	1.8/1.4	0.4/0.2	0.2/0.2
Skin	8.9	1.7	0.9
Spinal cord	10.1	2.1	0.9

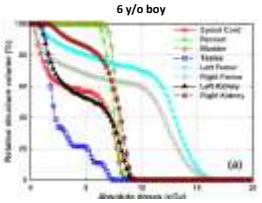
Son K, et al. Radiat Prot Dosim 2016

- The choice of kVp affects organ doses.
- Newer version CBCT reduced organ doses from cGy to mGy ranges.

Estimated organ doses from IGRT procedures

Default pelvis protocol
(Varian OBI, 125kV, 80mA, 13ms, 364°, half fan bowtie filter)

6 y/o boy



Deng J, et al. Int J Radiat Oncol Biol Phys 2012

Default pelvis protocol
(Varian OBI v1.4, 125kVp, 80mA, 13ms, 360°, half fan bowtie filter)

5 y/o boy

OAR/mGy	Pelvis
R/L kidney	33/31
Bladder	32
Prostate	26
rectum	29

5 y/o girl

OAR/mGy	Pelvis
R/L ovary	29/29
Uterus	29
Vagina	27

Son K, et al. Radiat Prot Dosim 2016

Pelvic organ doses are in the cGy range if default adult pelvis protocol was used for a 5 y/o.

Total dose could add up to 1Gy if such protocol was used daily.

Should we worry about the effect of IGRT doses?

- Although much lower than target dose, IGRT doses could be equal to or greater than peripheral doses from therapeutic beams (especially for scanning protons)
- Level of clinical evidence?
  - Increased risk of leukemia and brain cancer in children receiving diagnostic CT

Excess relative risk of 0.04 and 0.03 per mGy for leukemia and brain cancer from UK and Australian studies (Pearce et al. Lancet 2012, Matthews et al. BMJ 2013)
Excess relative risk of 0.86 per 100 mGy for brain cancer from Dutch study (Meulepas et al. JNCI 2019)

However, the French study (Journy et al. BJC 2015, J Radiol Prot 2016) showed no significant risk if cancer predisposing factors were adjusted.

epi-CT study (9 European national cohorts) is ongoing.

Should we worry about the effect of IGRT doses?

- Level of clinical evidence?
  - Higher incidence of second cancers in in-field tissues receiving medium-to-high doses Peaked at the area surrounding the PTV (Diallo et al. IJROBP 2009)

Diallo et al. IJROBP 2009

- Some normal tissues may have no or very low thresholds (e.g., thyroid, ovary, testis, bone marrow). Adding IGRT doses to doses from therapeutic beams may increase the risk of normal tissue toxicity. PENTEC group will provide pediatric organ-specific tolerance guidelines.

Recommendations on reducing imaging dose

- Recommendations from AAPM TG 180, ACR-AAPM and ACR-ASTRO technical standard, literature publications
- Official COG recommendations will be available later this year.
- Balance of clinical task performance and imaging dose reduction (don't overkill)
- Some strategies are presented here

  Create dedicated protocols for younger children
  Use adult low does protocols for children (e.g., adult low dose head for pediatric head, adult H&N for pediatric body)
  Choose imaging setting for specific tasks (marker, bony anatomy, soft-tissue detectability)
  Use collimation to reduce the imaged length/volume to block sensitive OARs
  Smaller field-of-view when appropriate (e.g., partial view of body may be sufficient for registration)
  Choose appropriate KV and mAs (most suitable exposure setting)
  Avoidance of organ at risk by using partial arc CBCT (gantry rotation start-stop angles)
  Reduce the chance of repeated imaging due to difficulty in adjusting patient position
  Bowtie filters and anti-scatter grid use
  Upgrade image guidance equipment
  Proper calibration, improving imaging technology by vendors
  Training of image equipment operators
  Ensure consistent patient setup and immobilization
  Supplement with non-ionizing radiation techniques (e.g., surface imaging, optical imaging)

Summary

- What we found in the COG survey
  - Most radiation oncologists recommended daily image guidance
  - Volumetric image guidance not as prevalent as in adults
  - 40% indicated scan setting (kVp/mAs) not adjusted for children because of lack of guidelines
- What can you do in the mean time as a physicist?
  - Review CBCT practice for children in your institution
  - Know your IGRT doses
  - Don't use adult protocols without modifications for young children and infants
  - Consult with your diagnostic imaging physicist colleague
  - Discuss with physicians and apply strategies easy to implement first
- Opportunities
  - Practice guidelines and research (e.g., beyond dose reduction)
  - Vendors to facilitate creation of site-specific pediatric protocols
  - Join COG physics committee to contribute

Acknowledgment

Members of COG survey team

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