COG GUIDELIENS FOR PEDIATRIC IGRT

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Joint ICTP-IAEA Workshop on Radiation Protection in Image-Guided Radiotherapy (IGRT)
Trieste, Italy, 7-11 October 2024

Disclosures

- Nothing to disclose
- Any reference to commercial products does not imply endorsement

Outline

- Introduction
- Children's Oncology Group Survey and Recommendations
- Pediatric Imaging Dose Optimization
- Summary and Conclusions

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Introduction

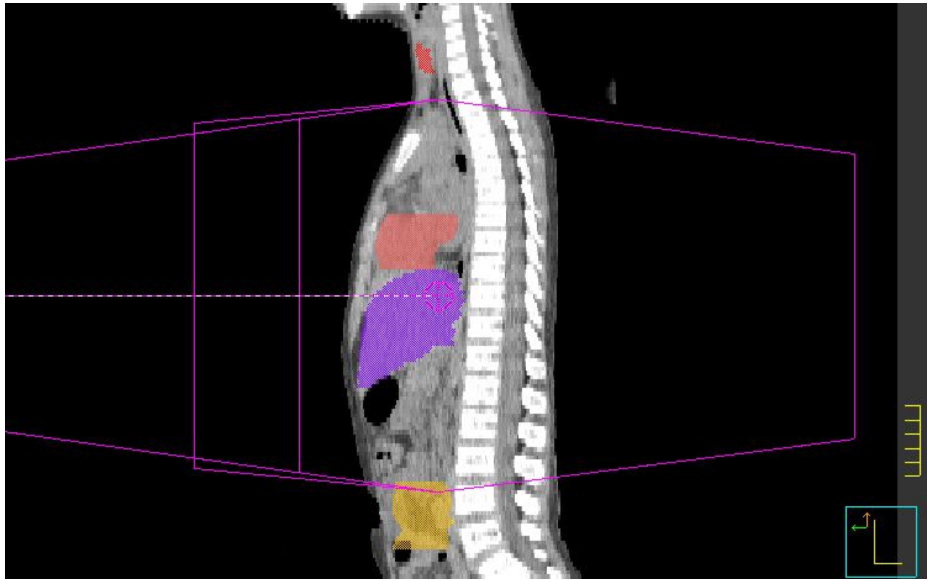
- Use of IGRT in pediatric radiation therapy helps to optimize the treatment and potentially improve the outcome
- But, any excess dose to patient is of importance, and there have been reports on the secondary cancer risks to children from added imaging radiation exposure

Introduction

- The image gently alliance recommends using lower radiation doses when imaging children

Imaging Dose and Pediatric Patients

- Smaller body size --- Same imaging techniques/protocol
  - Higher overall dose
  - More normal organs included within the imaged area



Extent of imaged volume for a 9-year-old using an M20 Cassette

Imaging Dose and Pediatric Patients

- Enhanced organ-at-risk dose within and outside the treatment area may lead to <u>secondary cancer risk</u>
  - Children are 10 times more sensitive to radiation induced cancers than adults (Hall 2006)
  - Children live much longer than adults post RT

  <u>Dose reduction methods and site-specific protocols more critical for children</u>

Practical Radiation Oncology (2014) 4, 336-341

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Original Report

Practice patterns of photon and proton pediatric image guided radiation treatment: Results from an International Pediatric Research Consortium

Sara R. Alcorn MD, MPH [a], Michael J. Chen MD [b], Line Claude MD [c], Karin Dieckmann MD [d], Ralph P. Ermoian MD [e], Eric C. Ford PhD [a,e], Claude Malet MD [c], Shannon M. MacDonald MD [f], Alexey V. Nechesnyuk MD [g], Kristina Nilsson MD, PhD [h], Rosangela C. Villar MD [i], Brian A. Winey PhD [f], Erik J. Tryggestad PhD [a,j], Stephanie A. Terezakis MD [a,*]

-Survey of 7 institutions on their IGRT practice patterns

-57% of photon institutions used lower dose protocols
(Proton facilities used kV planar imaging)

-Site-specific protocols varied across institutions

Journal of Medical Imaging and Radiation Sciences 49 (2018) 265-269

Journal of Medical Imaging and Radiation Sciences

Journal de l'imagerie médicale et des sciences de la radiation

www.elsevier.com/locate/jmir

Research Article

Image-Guided Radiotherapy in Paediatrics: A Survey of International Patterns of Practice

Verna Wall, BSc[a], Laure Marignol, PhD[a*] and Nazmy ElBeltagi, MD[bc]

[a] *Applied Radiation Therapy Trinity, Discipline of Radiation Therapy, School of Medicine, Trinity College Dublin, Dublin, Ireland*
[b] *St Luke's Radiation Oncology Network, Dublin, Ireland*
[c] *National Cancer Institute, Cairo University, Giza, Egypt*

-Survey of 119 international sites (43 responses received)

-Most lacked size-specific IGRT protocols accounting for patient age/size

Radiotherapy and Oncology 190 (2024) 109963

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Original Article

Paediatric CBCT protocols for image-guided radiotherapy; outcome of a survey across SIOP Europe affiliated countries and literature review

Daniella Elisabet Østergaard[a,b,1,*], Abigail Bryce-Atkinson[c,1], Mikkel Skaarup[a], Bob Smulders[a,d], Lucy Siew Chen Davies[e], Gillian Whitfield[f,g], Geert O. Janssens[h,i], Lisa Lyngsie Hjalgrim[j], Ivan Vogelius Richter[a,b], Marcel van Herk[c], Marianne Aznar[c,1], Maja Vestmø Maraldo[a,1]

-Survey of 246 centers on their pediatric CBCT protocols (50 response from 25 countries received)

-A wide range of technical settings employed, hence the need to optimize pediatric CBCT protocols

- These three surveys indicate there is a need for pediatric-specific imaging protocols and protocol optimization

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Dzierma *et al. Radiation Oncology* (2018) 13:168
https://doi.org/10.1186/s13014-018-1109-8

Radiation Oncology

RESEARCH Open Access

Imaging dose and secondary cancer risk in image-guided radiotherapy of pediatric patients

Yvonne Dzierma*, Katharina Mikulla, Patrick Richter, Katharina Bell, Patrick Melchior, Frank Nuesken and Christian Rübe

- Retrospective imaging dose calculation on 11 Pediatric Hodgkins cases

- Calculated excess average risk of developing a secondary carcinoma of lung or breast based on OAR DVH values

- Using planar MV imaging or kV CBCT results in lower risk than MV CBCT

- Risk can be reduced if breasts are spared from imaging dose, i.e. “under the couch” imaging

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The Children's Oncology Group (COG), a National Cancer Institute supported clinical trials group, is the world's largest organization devoted exclusively to childhood and adolescent cancer research. The COG unites more than 10,000 experts in childhood cancer at more than 200 leading children's hospitals, universities, and cancer centers across North America, Australia, and New Zealand in the fight against childhood cancer.

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DOI: 10.1002/pbc.28629

Pediatric Blood & Cancer SIOP aspho The American Society of Pediatric Hematology/Oncology WILEY

CLINICAL PRACTICE GUIDELINES

Practice patterns and recommendations for pediatric image-guided radiotherapy: A Children's Oncology Group report

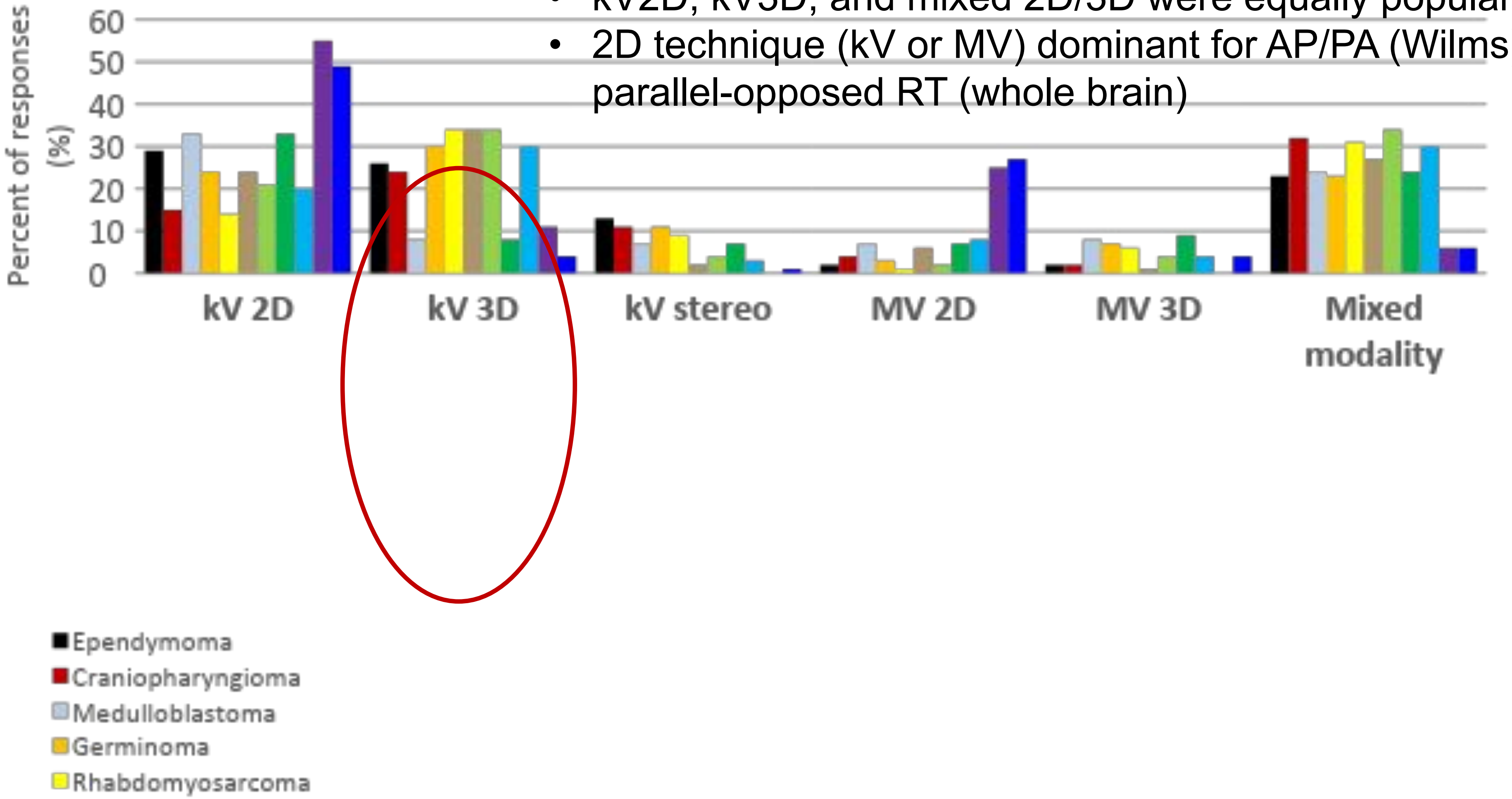
Chia-ho Hua[1,*] | Tamara Z. Vern-Gross[2,*] | Clayton B. Hess[3,4] | Arthur J. Olch[5] | Parham Alaei[6] | Vythialingam Sathiaseelan[7] | Jun Deng[8] | Kenneth Ulin[9] | Fran Laurie[9] | Mahesh Gopalakrishnan[7] | Natia Esiashvili[4] | Suzanne L. Wolden[10] | Matthew J. Krasin[1] | Thomas E Merchant[1] | Sarah S. Donaldson[11] | Thomas J. FitzGerald[9] | Louis S. Constine[12] | David C. Hodgson[13] | Daphne A. Haas-Kogan[14] | Anita Mahajan[15] | Nadia N. Laack[15] | Karen J. Marcus[14] | Paige A. Taylor[16] | Verity A. Ahern[17] | David S. Followill[16] | Jeffrey C. Buchsbaum[18] | John C. Breneman[19] | John A. Kalapurakal[7]

Introduction

- The report describes practice patterns of pediatric IGRT based on a member survey
- The survey sent to 347 individuals between Oct. and Dec. 2017
- Received 168 evaluable responses from 105 radiation oncologists and 63 medical physicists

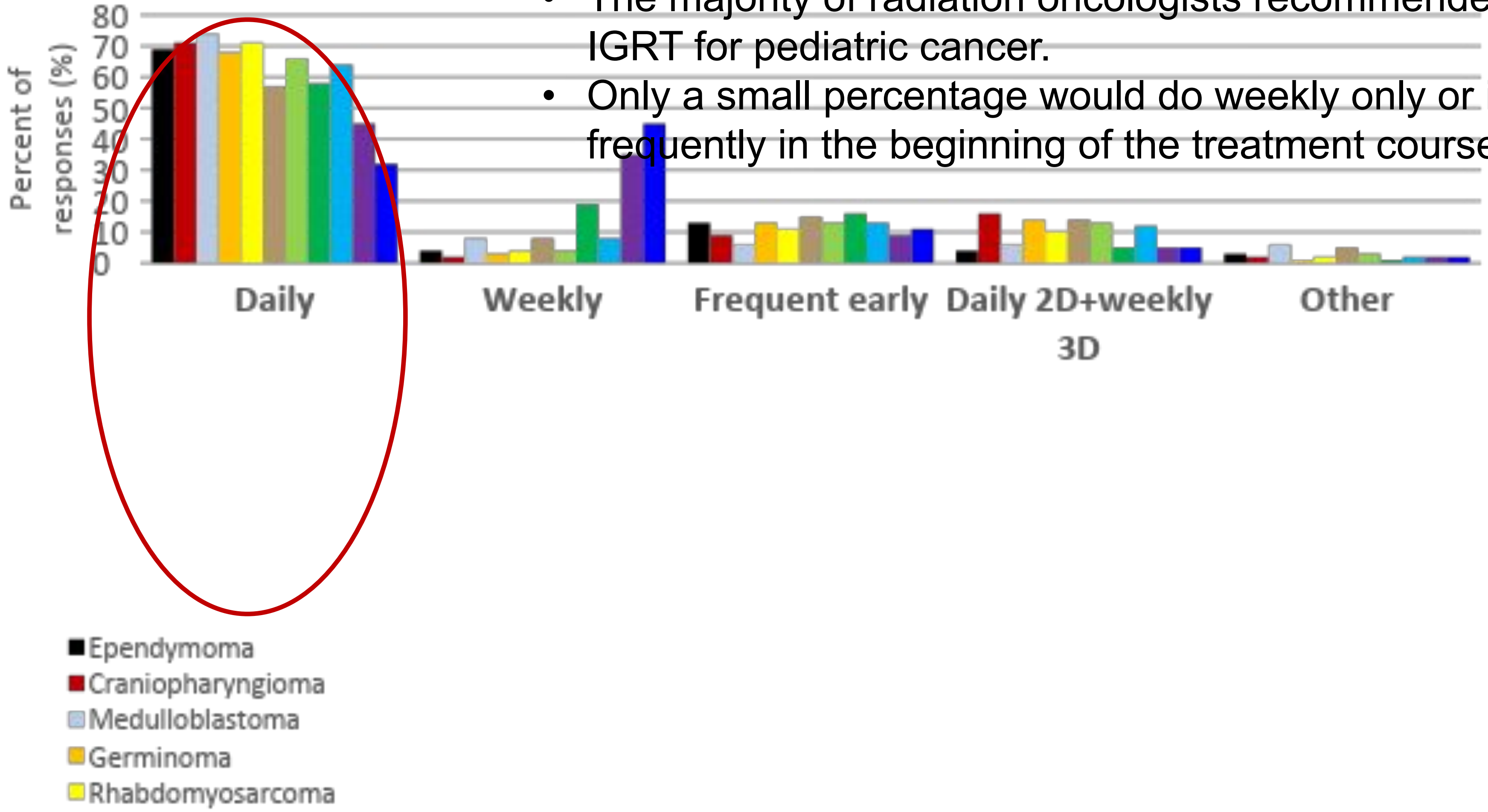
Pediatric IGRT Method Employed

- kV2D, kV3D, and mixed 2D/3D were equally popular
- 2D technique (kV or MV) dominant for AP/PA (Wilms) and parallel-opposed RT (whole brain)



Graphs Courtesy Chiaho Hua

Pediatric IGRT Method Employed

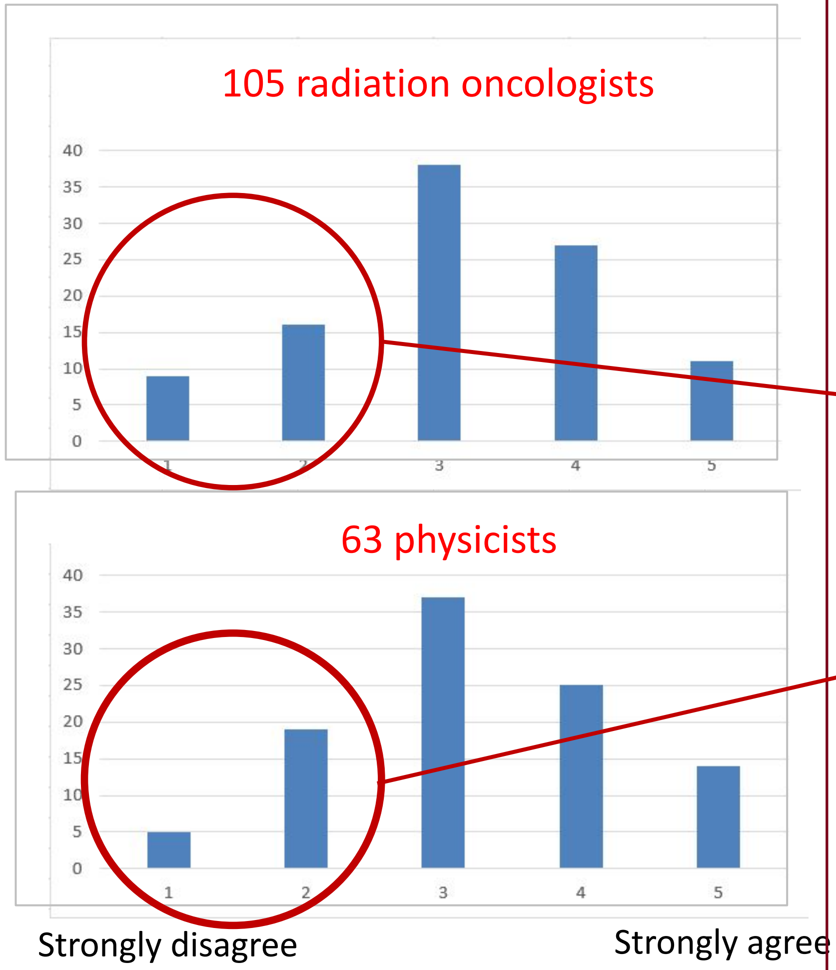


- The majority of radiation oncologists recommended daily IGRT for pediatric cancer.
- Only a small percentage would do weekly only or image frequently in the beginning of the treatment course.

Graphs Courtesy Chiaho Hua

Significance of the IGRT Dose

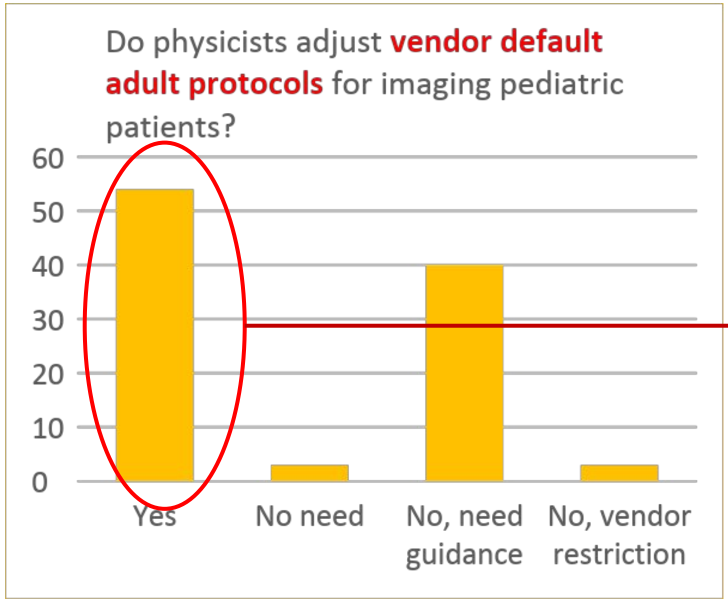
IGRT imaging dose poses a **non-negligible risk of secondary cancer** and needs to be lowered



~30% of respondents do not see the need to lower the imaging dose

Graphs Courtesy Chiaho Hua

Reducing the Imaging Dose



Over 50% of physicists adjust the default protocols

Imaging dose documentation/subtraction:

89% **did not document** IGRT dose

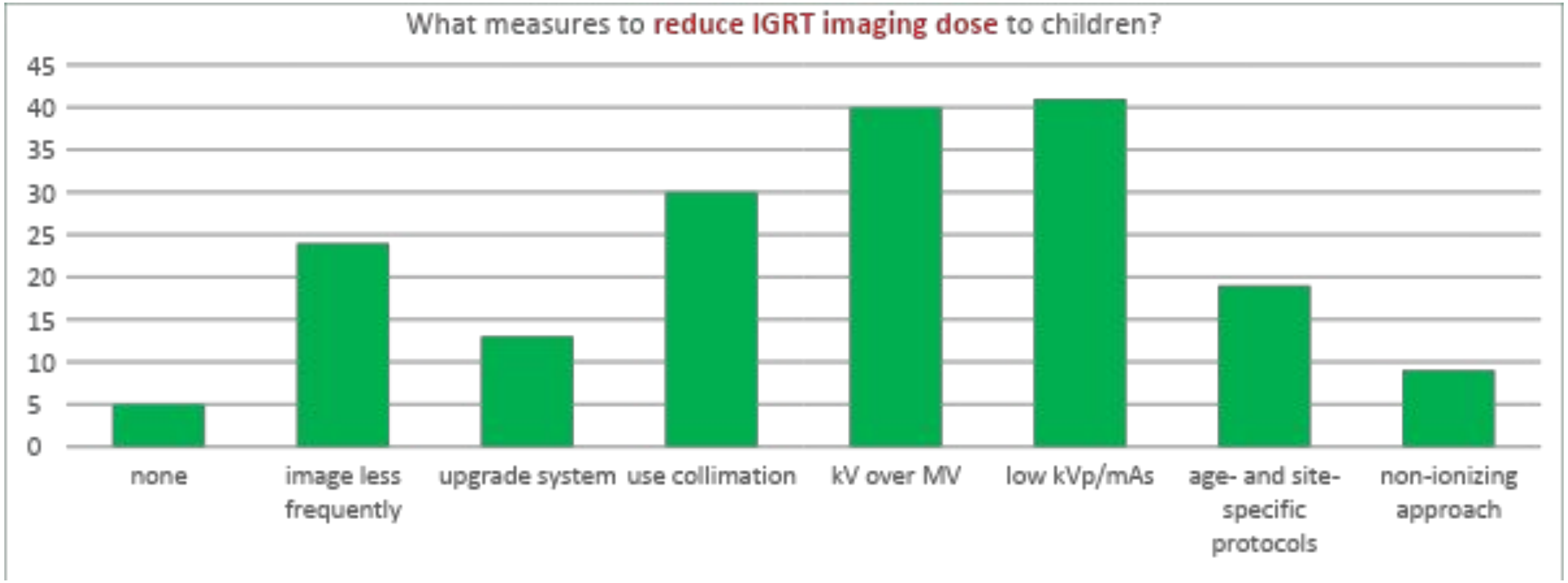
95% **did not subtract** IGRT dose from prescribed dose

64% considered **imaging dose insignificant** compared to prescribed dose

62% **not possible to incorporate** imaging dose accurately into treatment plan

Graphs Courtesy Chiaho Hua

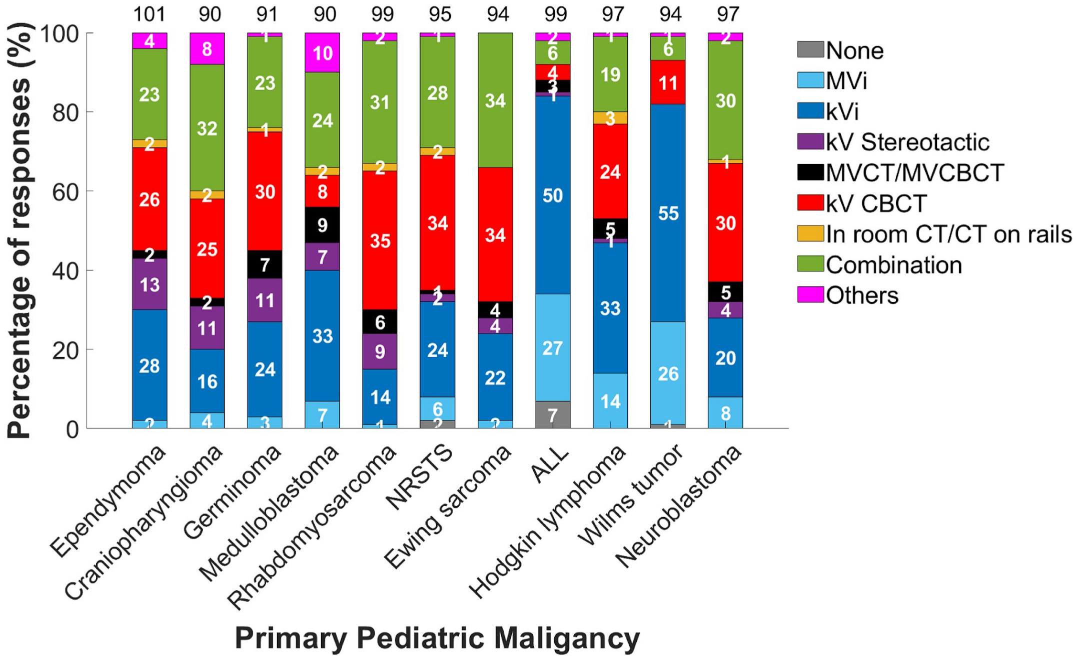
Reducing the Imaging Dose



Graphs Courtesy Chiaho Hua

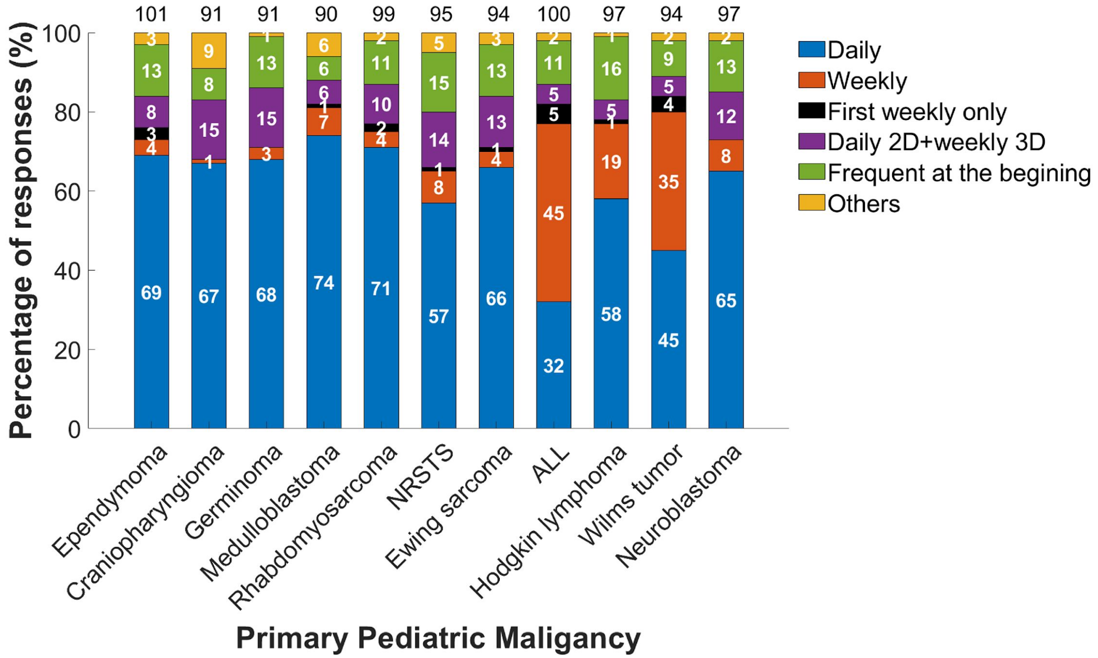
Image Guidance Practice Patterns

Image guidance modality



kV CBCT

Image guidance frequency



Daily

Graphs Courtesy Chiaho Hua

Risks of Secondary Malignancy vs. IGRT Benefits

- This report states that accurately predicting adverse effects and risks from doses of less than 100 mSv is challenging

- And it cautions when calculating secondary cancer risk in patients receiving radiotherapy based on models derived from atomic-bomb survivors

Risks of Secondary Malignancy vs. IGRT Benefits

- However, there are published reports on cancer risks from imaging dose

- And the risk per Gy has been determined to be lower for therapeutic irradiation than other exposures

Hua et al. *Pediatr Blood Cancer* 2020; e28629

Risks of Secondary Malignancy vs. IGRT Benefits

- Despite risks associated with image guidance, its potential advantages must be acknowledged

- The significantly reduced setup margin will decrease the dose not only to adjacent healthy tissues near the target that are exposed to higher doses of radiation but also to those tissues distal from the target that are exposed to lower doses, thereby diminishing the risk of secondary cancers

Risks of Secondary Malignancy vs. IGRT Benefits

- As a result of the use of smaller margins and better positioning with IGRT, higher therapeutic doses are more frequently delivered with modern advanced radiotherapy techniques

- The benefits of being able to make informed decisions about margins, adapt the target volume during treatment, and ensure accurate treatment delivery outweigh the risk of secondary cancer that results from diagnostic imaging or other low-dose exposures

Recommendations

Image Guidance Modality

- Guiding 2D treatments with 2D kV imaging is generally sufficient without 3D imaging and normally gives a lower imaging dose.

- These treatments may include whole-brain irradiation for acute lymphocytic/lymphoblastic leukemia, nodal irradiation fields for lymphoma, or flank/whole-abdomen radiotherapy for Wilms tumor.

Image Guidance Modality

- 3D imaging is recommended when bony landmarks are not reliable surrogates for tumor positions, when margins are small, or when rotational corrections are needed without the guidance of implanted fiducials.

- Consider 3D imaging to reduce margins before prioritizing 2D imaging to reduce imaging dose.

Image Guidance Modality

- Do not use MV imaging for more than verifying the field shape on the first fraction unless the low-dose setting is adopted.

- Be cautious about electron therapy and light field verification without image guidance for superficial tumors such as chest wall sarcoma. The majority of pediatric radiation oncologists favor conformal treatment with image guidance.

Imaging Frequency

- Do not rely solely on weekly imaging at the start of 3D CRT, including CSI beam placement. Consider reducing imaging frequency to weekly only after daily imaging has confirmed stable anatomy.

- Do not reduce the imaging frequency solely in an effort to reduce the imaging dose. The benefits of accurate tumor targeting with reduced margins may outweigh the risk from the imaging dose.

Imaging Frequency

- Minimize repeated imaging in a session to adjust the patient position. Improve patient setup procedures and immobilization devices to minimize multiple exposures.

Imaging Dose Reduction

- When both MV and kV imaging are available on the same treatment delivery system, choose kV to reduce imaging dose to patients.

- Use field-limiting devices (e.g., blades, collimators, cassettes) to block radiation-sensitive organs (e.g., lens, thyroid, gonads) if target verification is not compromised.

Imaging Dose Reduction

- When volumetric image guidance is preferred in situations where only bony anatomy is used for registration (e.g., for rotational correction), utilize institutional 3D low-dose image-acquisition techniques.

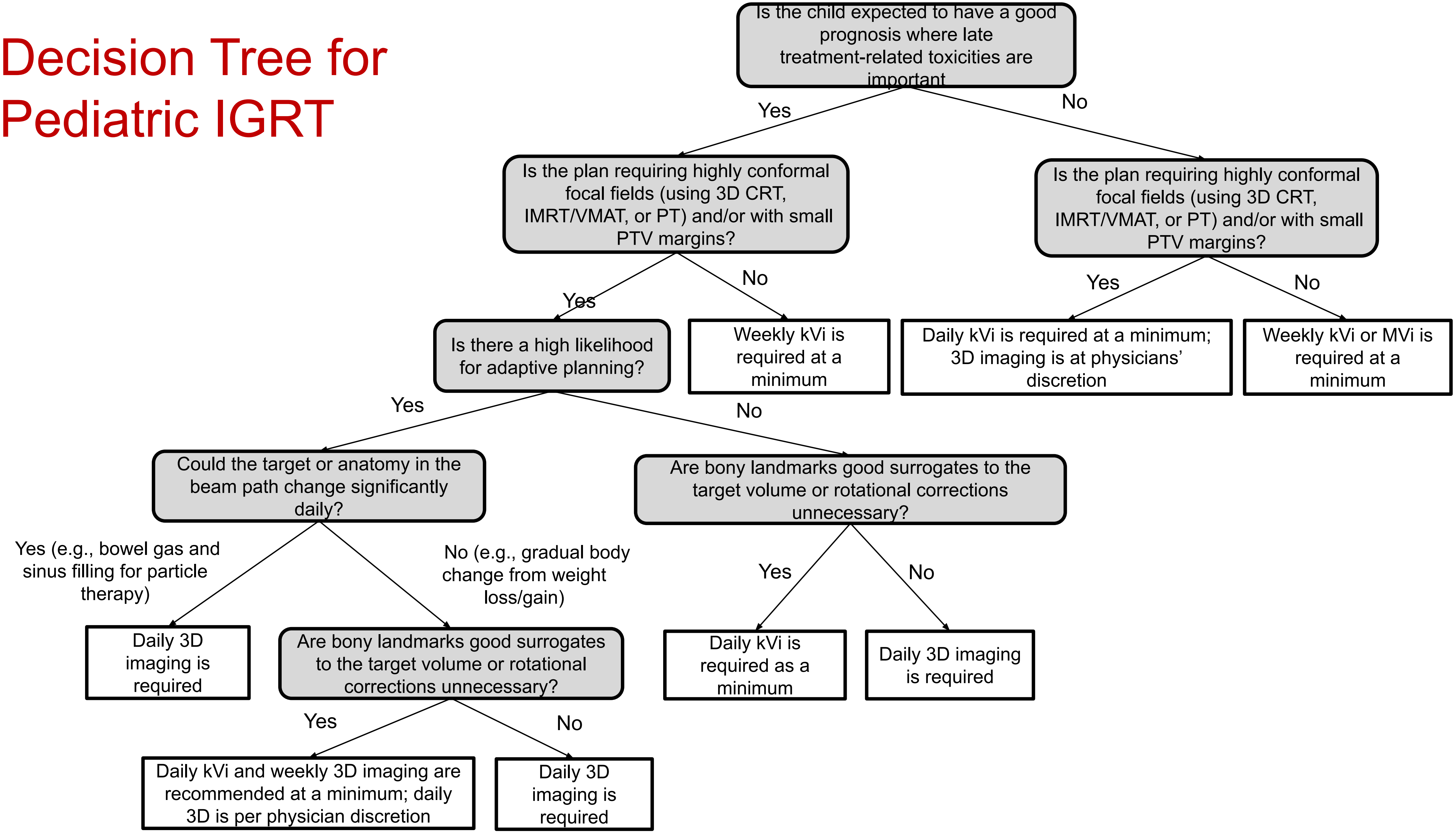
- Superior guidance can still be provided without exposing patients to a significantly higher dose than that with 2D X-rays.

Imaging Dose Reduction

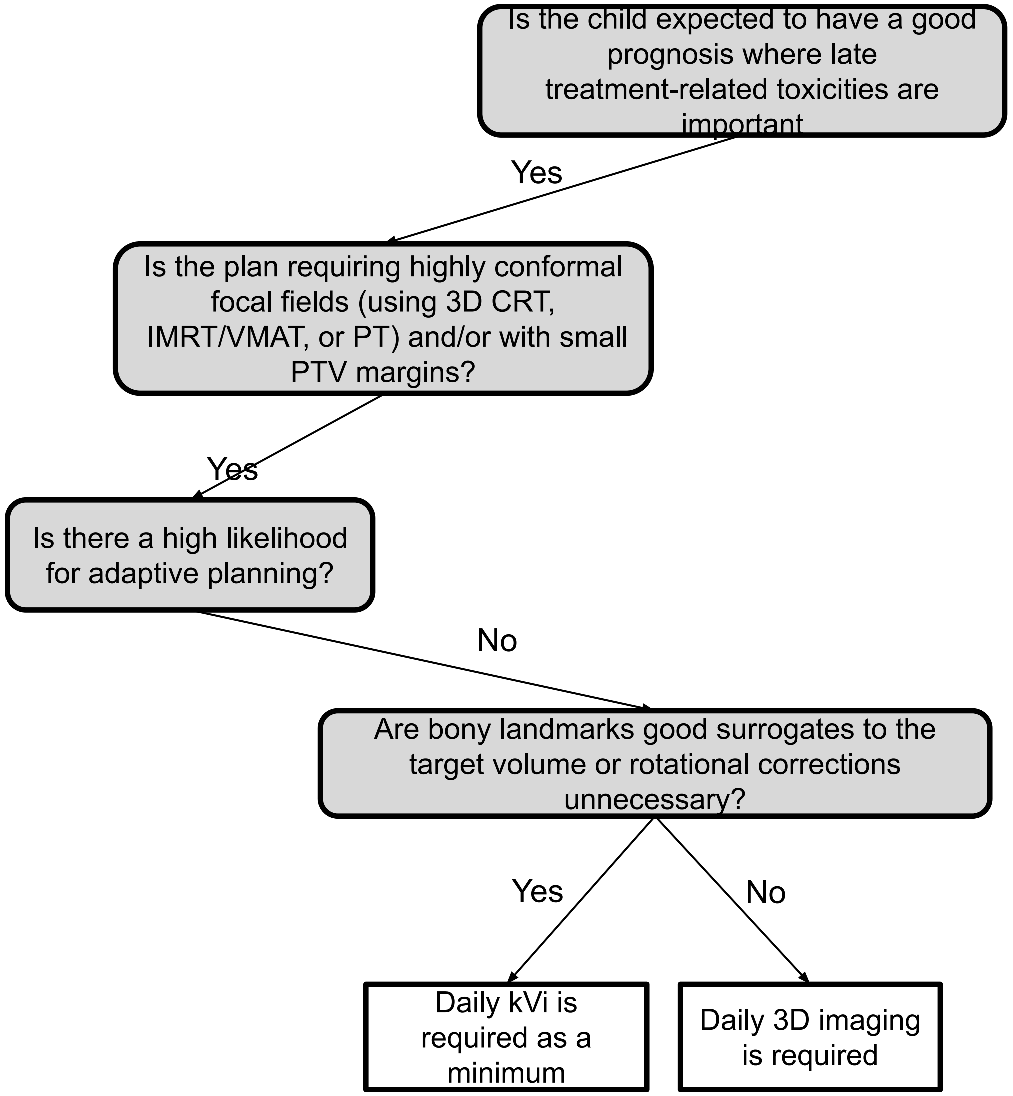
- Do not directly apply imaging guidance techniques designed for adults to young children without modifications. If it is not possible to modify technique parameters such as mAs, consider using the vendor's low-dose techniques.

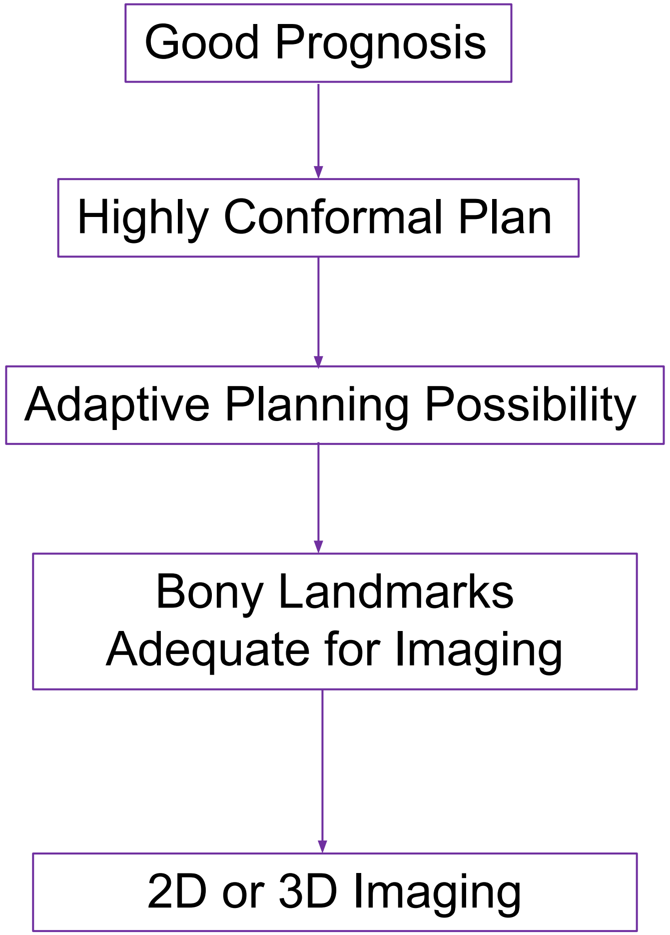
- Consider using non-ionizing position verification methods (e.g., surface imaging or MRI guidance) to replace or supplement ionizing radiation methods whenever possible.

Decision Tree for Pediatric IGRT



Decision Tree for Pediatric IGRT





Representative Pediatric Organ Dose Data

	Low dose/Head and Neck Protocol ----- S20 Cassette, 100 kVp, 0.1 mAs/frame, 205 degree rotation, 366 frames												
	Bladder	Rectum	Bowel	Rt Kidney	Lt Kidney	Liver	Stomach	Spleen	Heart	Rt Lung	Lt Lung	Esoph.	Gonads
2-5 age group	1.1	0.8	1.2	0.7	1.1	0.9	1.3	1.3	1.2	0.9	1.1	0.9	0.9
6-10 age group	1.0	0.7	0.9	0.6	0.8	0.8	1.1	1.1	1.1	0.8	1.1		1.0
11-15 age group	0.7	0.5		0.5	0.9	0.7	1.1	1.1	1.0	0.7	0.9	0.8	
	Brain	Brainstem	Chiasm	Rt ON	Lt ON	Rt Cochlea	Lt Cochlea	Rt Eye	Lt Eye	Rt Lens	Lt Lens	Pituitary	Thyroid
2-5 age group	0.9	0.9	1.05	1.1	1.3	0.8	1.3	1.25	1.6	1.35	1.7	1.1	1.2
6-10 age group	1.0	1.0	1.1	1.0	1.3	0.8	1.3	1.2	1.6	1.6	1.6	1.0	1.0

Average organ dose (cGy), 10 imaging sessions, all organs fully within imaged volume, couch ignored. No of patients: 7 in 2-5 group, 5 in 6-10 group, 4 in 11-15 group, TPS used for dose calculations.

Hua et al. *Pediatr Blood Cancer* 2020; e28629

Representative Pediatric Organ Dose Data

	Medium dose/Thorax Protocol ---- L20 Cassette, 120 kVp, 0.25 mAs/frame, 360 degree rotation, 660 frames													
	Bladder	Rectum	Bowel	Rt Kidney	Lt Kidney	Liver	Stomach	Spleen	Heart	Rt Lung	Lt Lung	Esoph.	Thyroid	Gonads
2-5 age group	5.5	4.6	5.2	5.2	4.9	5.0	5.0	5.1	5.5	4.8	4.7	5.1	5.8	4.9
6-10 age group	5.1	4.5	4.3	4.1	4.4	4.7	4.3	4.6	4.8	4.6	4.4		5.3	4.4
11-15 age group	3.3	3.4		4.2	4.1	4.1	4.6	4.3	4.5	4.0	4.0	5.0	4.3	
	High dose/Plevis Protocol --- M20 Cassette, 120 kVp, 1.0 mAs/frame, 360 degree rotation, 660 frames													
	Bladder	Rectum	Bowel	Rt Kidney	Lt Kidney	Liver	Stomach	Spleen	Heart	Rt Lung	Lt Lung	Esoph.	Thyroid	Gonads
2-5 age group	29.8	25.9	31.9	30.1	30.5	29.9	29.2	32.9	31.2	29.3	29.4	25.9	34.2	27.2
6-10 age group	26.8	24.5	24.7	23.4	24.2	25.9	25.3	24.6	27.8	26.1	25.7	33.1	33.4	23.6
11-15 age group	17.4	16.8		22.6	22.0	22.1	25.3	23.9	23.3	23.0	21.6	24.8	20.4	

Average organ dose (cGy), 10 imaging sessions, all organs fully within imaged volume, couch ignored. No of patients: 7 in 2-5 group, 5 in 6-10 group, 4 in 11-15 group, TPS used for dose calculations.

Hua et al. *Pediatr Blood Cancer* 2020; e28629

Representative Pediatric Organ Dose Data

	Medium dose/Thorax Protocol ---- L20 Cassette, 120 kVp, 0.25 mAs/frame, 360 degree rotation, 660 frames													
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2-5 age group	5.5	4.6	5.2	5.2	4.9	5.0	5.0	5.1	5.5	4.8	4.7	5.1	5.8	4.9
6-10 age group	5.1	4.5	4.3	4.1	4.4	4.7	4.3	4.6	4.8	4.6	4.4		5.3	4.4
11-15 age group	3.3	3.4		4.2	4.1	4.1	4.6	4.3	4.5	4.0	4.0	5.0	4.3	

To use the table, the dose values need to be scaled based on the kVp and total mAs of the imaging protocol used

Hua et al. *Pediatr Blood Cancer* 2020; e28629

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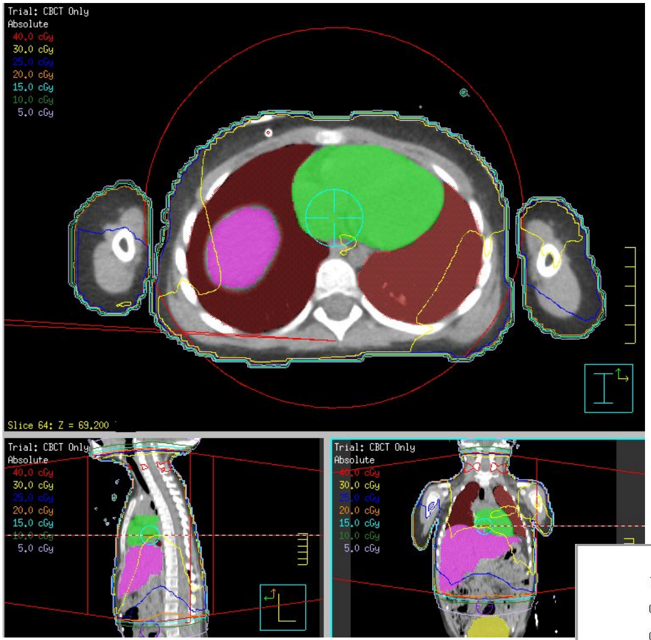
Optimizing the Imaging Dose

- Optimizing the imaging dose does not necessarily mean lowering it

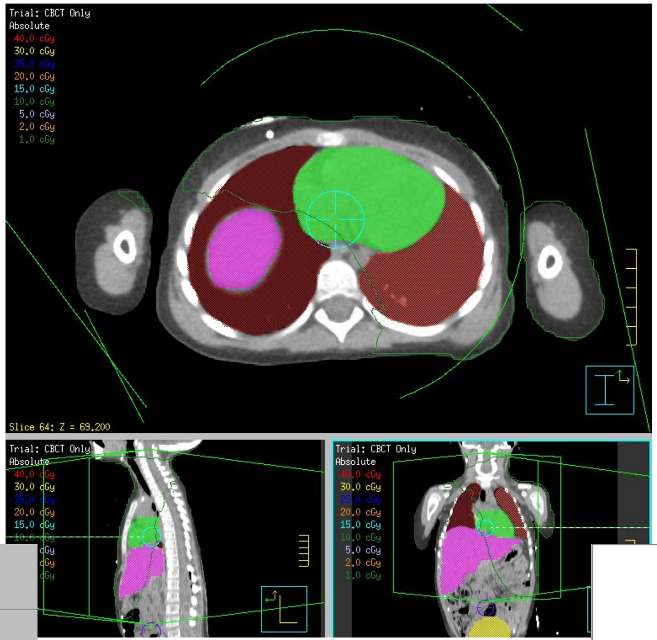
- However, in case of pediatrics, this almost always mean lowering the dose by adjusting imaging techniques designed for adults

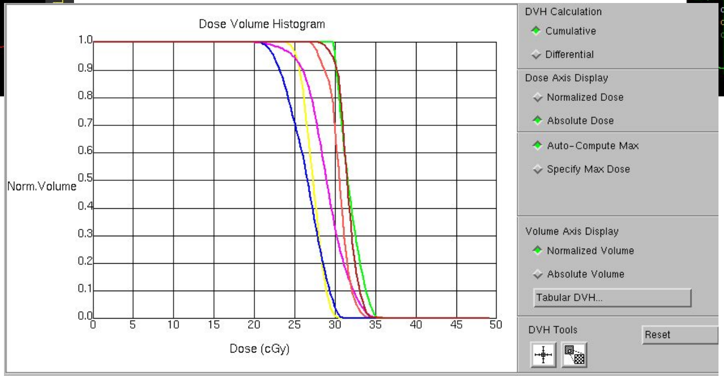
- This can easily be achieved by employing lower does protocols, or adjusting the imaging technique

Imaging Dose Reduction (Calculated for a 4-year old)



Over 20 fold decrease of imaging dose

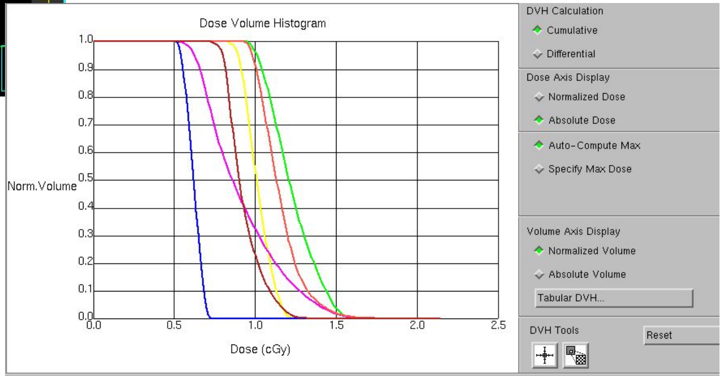




ROI Statistics

Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max
	Heart	CBCT Only	29.3	36.0	31.8	1.4	0.00 %	0.00 %
	L Kidney	CBCT Only	23.5	30.5	27.2	1.3	0.00 %	0.00 %
	Liver	CBCT Only	17.7	35.7	28.9	2.5	0.00 %	0.00 %
	Lt Lung	CBCT Only	26.7	35.8	30.5	1.3	0.00 %	0.00 %
	R Kidney	CBCT Only	20.4	31.0	26.3	2.3	0.00 %	0.00 %
	Rt Lung	CBCT Only	26.8	35.3	31.5	1.1	0.00 %	0.00 %

120 kVp, 660 mAs

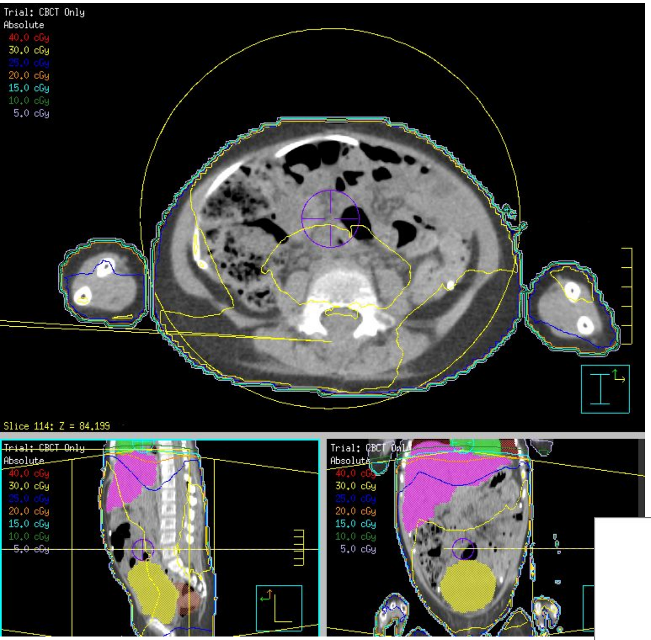


ROI Statistics

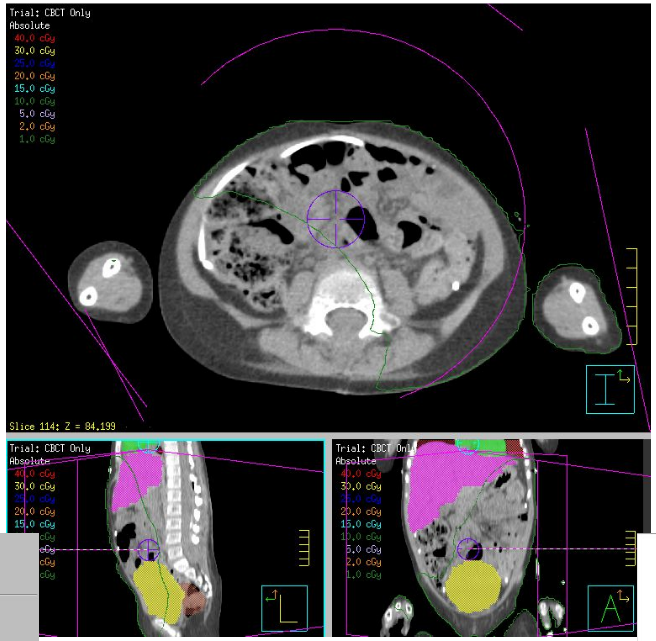
Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max
	Heart	CBCT Only	0.9	1.7	1.2	0.1	0.00 %	0.00 %
	L Kidney	CBCT Only	0.8	1.2	1.0	0.1	0.00 %	0.00 %
	Liver	CBCT Only	0.5	1.7	0.9	0.2	0.00 %	0.00 %
	Lt Lung	CBCT Only	0.9	1.7	1.2	0.1	0.00 %	0.00 %
	R Kidney	CBCT Only	0.5	0.7	0.6	0.0	0.00 %	0.00 %
	Rt Lung	CBCT Only	0.7	1.3	0.9	0.1	0.00 %	0.00 %

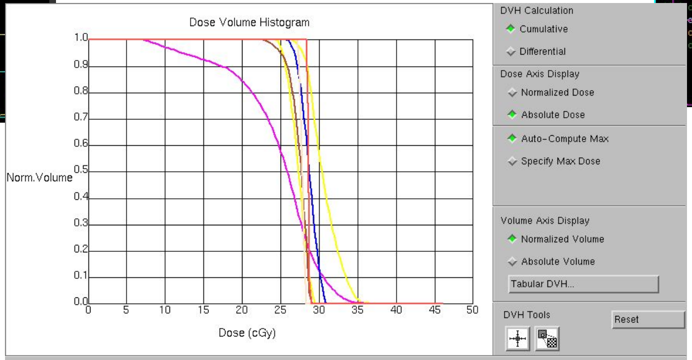
100 kVp, 36.6 mAs

Imaging Dose Reduction (Calculated for a 4-year old)



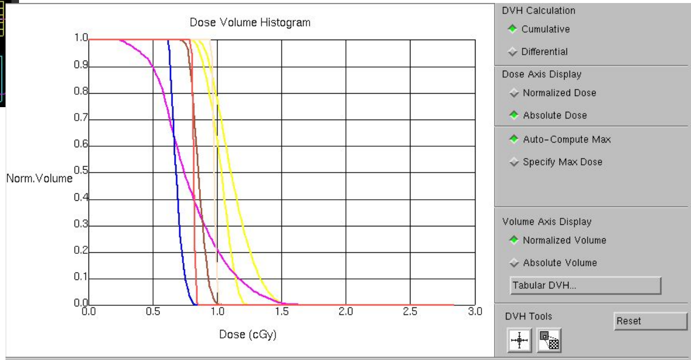
Over 20 fold decrease of imaging dose





Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max
	Bladder	CBCT Only	26.0	36.5	30.6	1.9	0.00 %	0.00 %
	L Kidney	CBCT Only	24.3	29.6	27.2	1.2	0.00 %	0.00 %
	Liver	CBCT Only	6.6	35.9	24.7	5.5	0.00 %	0.00 %
	R Kidney	CBCT Only	25.5	31.0	28.7	1.1	0.00 %	0.00 %
	Rectum	CBCT Only	22.7	29.2	27.4	1.2	0.00 %	0.00 %
	left ovary	CBCT Only	27.1	28.2	27.8	0.3	0.00 %	0.00 %
	right ovary	CBCT Only	28.3	28.9	28.6	0.1	0.00 %	0.00 %

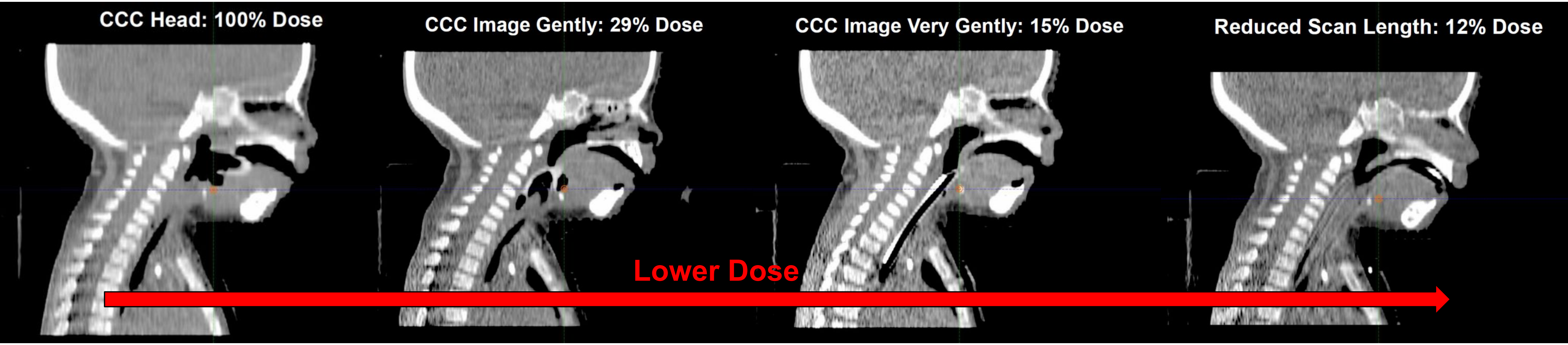
120 kVp, 660 mAs

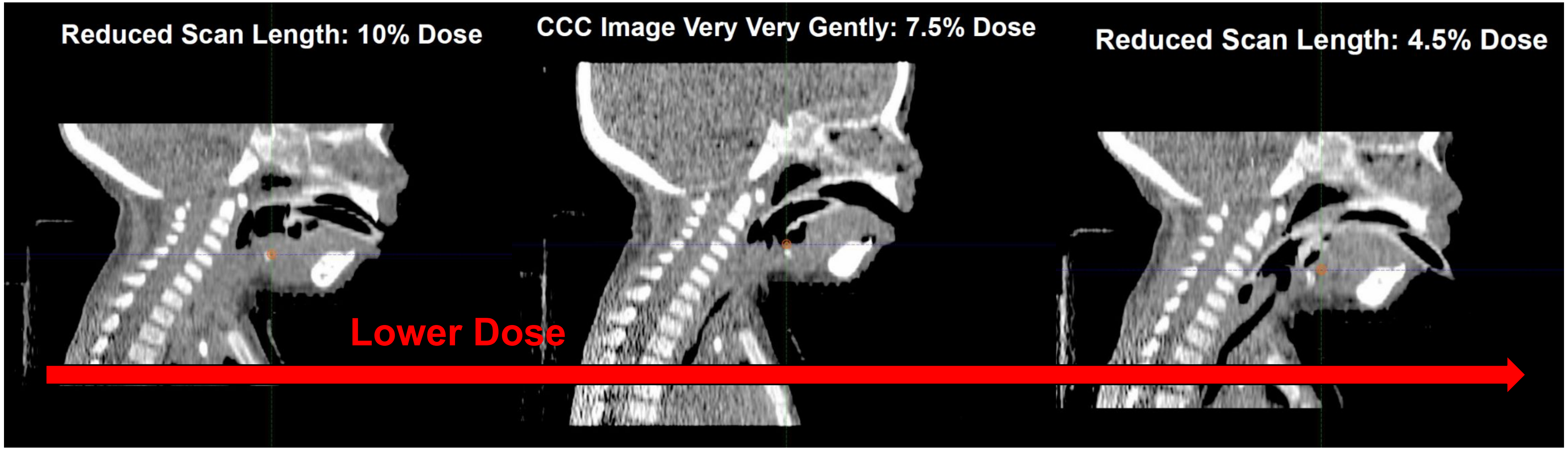


Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max
	Bladder	CBCT Only	0.8	1.6	1.1	0.1	0.00 %	0.00 %
	L Kidney	CBCT Only	0.8	1.2	1.0	0.1	0.00 %	0.00 %
	Liver	CBCT Only	0.2	1.6	0.8	0.3	0.00 %	0.00 %
	R Kidney	CBCT Only	0.6	0.8	0.7	0.0	0.00 %	0.00 %
	Rectum	CBCT Only	0.7	1.0	0.9	0.1	0.00 %	0.00 %
	left ovary	CBCT Only	0.9	1.0	1.0	0.0	0.00 %	0.00 %
	right ovary	CBCT Only	0.8	0.8	0.8	0.0	0.00 %	0.00 %

100 kVp, 36.6 mAs

Imaging Dose Reduction, Maintaining Image Quality



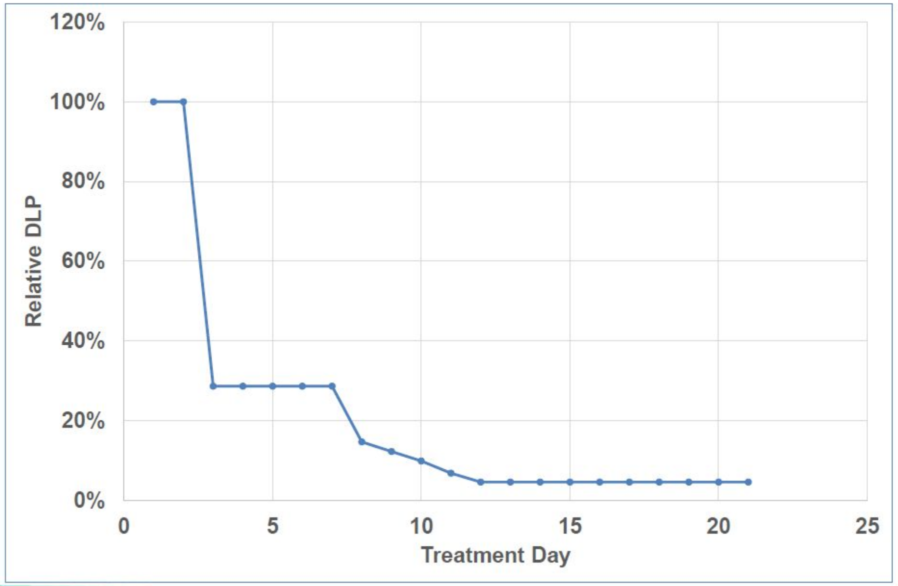


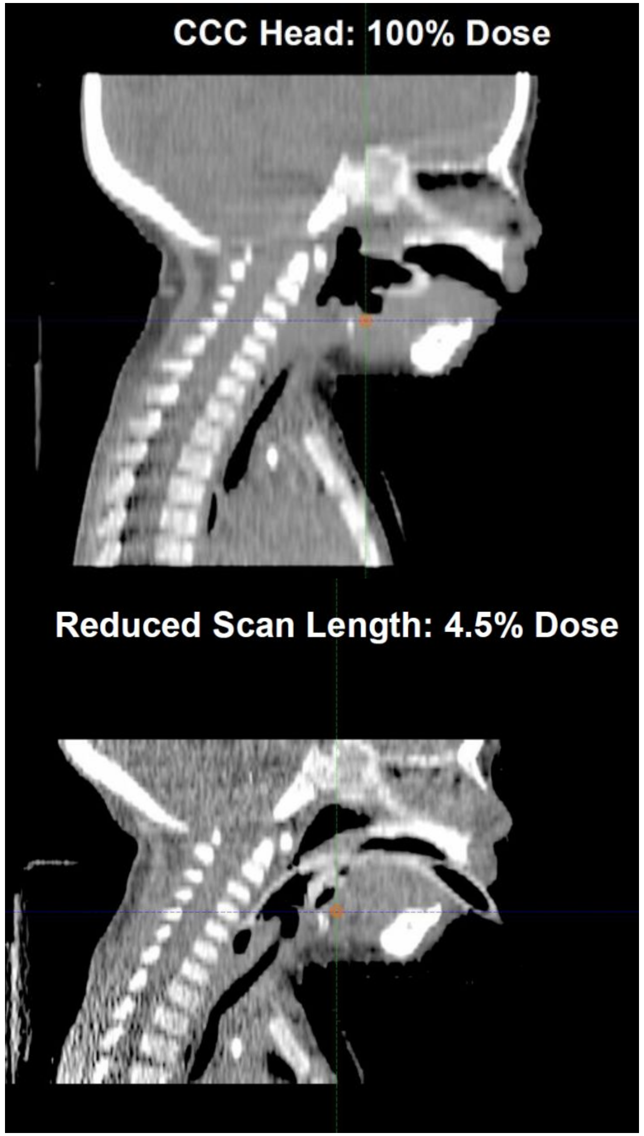
Images Courtesy Tim Wood, Hull University, UK

Imaging Dose Reduction, Maintaining Image Quality

Progression of dose reduction

NHS
Hull University
Teaching Hospitals
NHS Trust





Images Courtesy Tim Wood, Hull University, UK

Outline

- Introduction
- Children’s Oncology Group Survey and Recommendations
- Pediatric Imaging Dose Optimization
- Summary and Conclusions

Summary and Conclusions

- Optimizing the imaging dose in pediatric radiation therapy is important since children often live much longer than adults undergoing therapy, and their organs may not be developed at the time of treatment

- This, however, should not translate into sub-optimal imaging and treatment

Summary and Conclusions

- The Children's Oncology Group has published the results of a survey on IGRT practice patterns, as well as guidelines for pediatric IGRT

- It is possible to lower the imaging dose to smaller patients easily without compromising image quality


Questions?