The European survey on IGRT imaging for paediatrics

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Surveys on IGRT imaging for paediatrics

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IGRT improves RT accuracy and precission but it involves an additional dose (0.3 to 3 cGy)

Children have increased risk of radio-induced second malignancies:

-Age
-Genetic susceptibility
-Radiation dose

There is a lack of consensus guidelines on the optimal use of IGRT in pediatrics patients

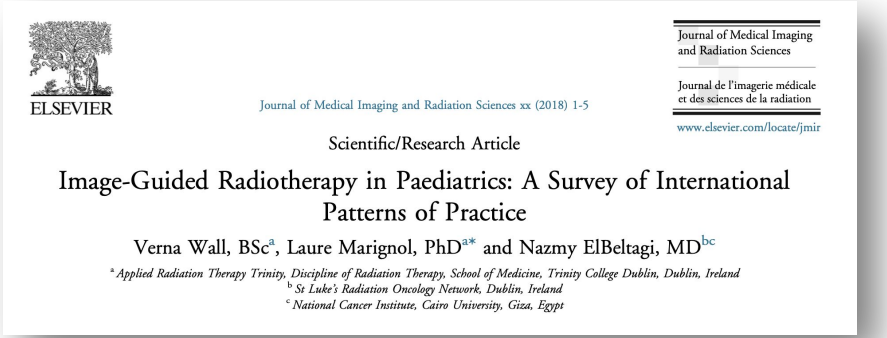
Manufacturer default image acquisition protocols, designed for adults, are used for children

There is a lack of guidelines for optimizing paediatric IGRT with low as reasonably achievable.

Low dose 3D protocols for children decrease the dose by a factor of 10 maintaining position accuracy.

Evaluation of the international patterns of practice of IGRT in pediatrics

2015: **Survey to the International Paediatric Radiation Oncology Society members**



ELSEVIER

Journal of Medical Imaging and Radiation Sciences xx (2018) 1-5

Journal of Medical Imaging and Radiation Sciences

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

www.elsevier.com/locate/jmir

Scientific/Research Article

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

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2020: Practice patterns and recommendations for Pediatric IGRT: A Childrens Oncology Group Report

2022: **Survey conducted among 246 SIOPE-affiliated centres (35 countries)**

Radiotherapy and Oncology 190 (2024) 109963

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

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Original Article

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

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Survey 2015

Data collected 1 sept-31 Oct 2015

Sent to 119 international Paediatric Radiation Oncology Society members
Eligible those centers treating adults and Paediatrics having IGRT capability
Aim: Evaluation of patterns of IGRT practice in paediatric vs adults

Survey description:

1. Five-item survey
2. Closed and open questions

Survey 2015

Response rate: 43/119

Only 16/35 had a **separate protocol** for paediatrics

3/16 IGRT individualized (number of fractions, dose, margins, treatment intent, treatment machine…)

Most respondants **SAME imaging frequency** for paediatrics and adults (71% torso, 74% CNS, 83% other sites)

50% daily imaging

19% individualized approach

Nearly half of the respondants use the **SAME scanning parameters** for adults and paediatrics

Survey 2015

Methods to reduce radiation exposure for IGRT

- Reduction imaging frequency: 5
- kV imaging : 4
- reduce kV and mAs: 2
- reduced field size : 2

Survey 2015

Recommendations

- Reduction of mAs for CBCT (40-100 mAs)
- Exposure parameters adapted to size/weight (not only to age)
- Education to Radiation Oncologists and RTTs on dose optimisation in IGRT
- Need for consensus recommendations to guide clinical decision-making on optimal IGRT use for paediatric patients
- Need for guidelines for size specific dose optimization approaches

Literature review on published paediatric CBCT protocols for CBCT (2022)

Table 1
Protocols extracted from the literature and grouped by the purpose of the study.

Author, year	Anatomy	Age (years)	Vendor	kVp	mAs	No. of projections	Bowtie Filter used	Image quality evaluation	Registration evaluation
OPTIMISATION STUDY									
Bryce-Atkinson, 2021 [9]	Mixed sites	6–13	Elekta	120	18–460.8	180–360	✓	✓	✓
Olch, 2021 [7]	HN, thorax, Pelvis	–	Varian	80–125	50–1080	–	–	–	✓
Bryce-Atkinson, 2020 [22]	Mixed sites	1–16	Elekta	100	5–32	200	✓	✓	✓
Huang, 2019 [26]	–	–	Varian	80	100	–	✓	–	✓
Alcorn, 2019 [8]	CNS	1–20	Elekta	100	31.5	183	×	✓	✓
Rao, 2019 [23]	Abdomen	1.5–9.2	Elekta	100–120	31.5–63	315	×	–	✓
De Jong, 2014 [27]	CSI	–	Elekta	–	10–32 mA, 10–40 ms†	–	✓	✓	✓
REPORTED PROTOCOLS									
Yuan, 2022 [28]	HN	–	Elekta	100	18.2	182	–		
Sheikh, 2022 [16]	Mixed sites	0–18	Hitachi*	100	–	–	–		
Uh, 2021 [29]	Abdomen/pelvis	1–23	Hitachi*	90–125	10–60	–	✓		
Huijskens, 2019 [30]	Abdomen, thorax	2–18	Elekta	120	10 mA, 10–40 ms†	180–760	–		
Guerreiro, 2019 [31]	Abdomen	1–8	Elekta	100	16 mA, 10 ms†	–	–		
Huijskens, 2018 [32]	Abdomen, thorax	8.6–17.9	Elekta	120	10 mA, 10 or40ms†	180–760	–		
Guerreiro, 2018 [33]	Abdomen	1–8	Elekta	100	16 mA, 10 ms†	–	–		
Huijskens, 2018 [34]	Abdomen, thorax, spine	2.2–17.8	Elekta	120	10 mA, 10 ms†	–	–		
Huijskens, 2017 [35]	Abdomen, CSI, thorax	2–18	Elekta	120	10 mA, 10 or40ms†	180–760	–		
Huijskens, 2015 [36]	Abdomen, thorax, spine	1.6–17.8	Elekta	–	–	–	✓		
DOSE CALCULATION STUDY									
Dzierma, 2018 [18]	Abdomen, thorax	5–17	Siemens	121	200–700	200–360	–		
Son, 2017 [37]	Mixed sites	5	Varian	100–125	72–720	360–655	✓		
Kim, 2016 [38]	Abdomen	5	Varian	125	40–80 mA, 10–25 ms†	650–700	✓		
Deng, 2012 [10]	Abdomen, CNS	2.75–6	Varian	60–125	80 mA, 13–25 ms†	–	✓		
Ding, 2010 [20]	HN, thorax, pelvis	2.6	Varian	100–125	10–80 mA, 20–25 ms†	–	✓		

✓= yes, ×= no, - = not specified, * = protons centre, † = mAs per projection, otherwise total mAs is reported directly from the study or by calculation from the reported number of projections and mAs per projection, CSI = craniospinal irradiation, HN = head and neck, CNS = central nervous system.

D. E. Ostergaard et al. Radiother. Oncol. 2024

Heterogeneous settings and parameters suggest lack of consensus

Some of the optimization studies did not address visual image quality (4/7)

Survey SIOPE 2022

Data collected 6 sept-22 Oct 2022

Sent to 236 centers/ 35 SIOPE affiliated countries

Survey description:

1. Demographic information
2. CBCT settings for brain/head site
3. CBCT settings for adbodminal sites

Data analysis

Removal of duplicated responses

When ranges of quantitative parameters were reported, two protocols were generated (lowest and top values)

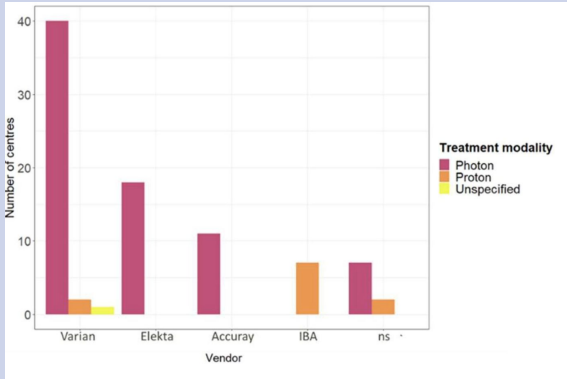
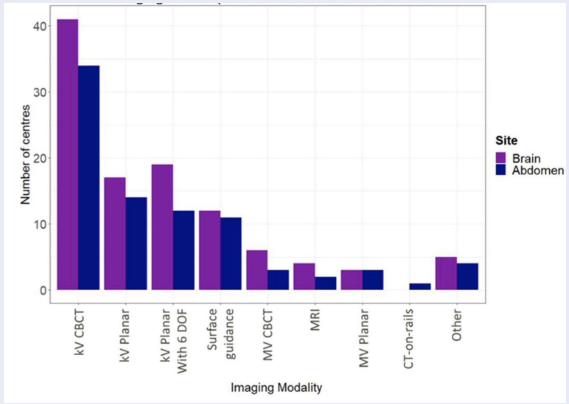
CBCT protocols reporting <10 projections removed from analysis

Suspected errors clarified with responders

Survey SIOPE 2022

Responses:

50/246 Centers
25/35 European countries

Demographic information	
Treatment modality	44 centers Photons EBRT 10 centers Protons EBRT
Patients treated per year	< 10 p/y 11 centres 11-25 p/y 12 centres 26-50 p/y 12 centres 51-100 p/y 7 centres 101-150 p/y 7 centres > 150 p/y. 2 centres
Vendors	
Imaging modalities	

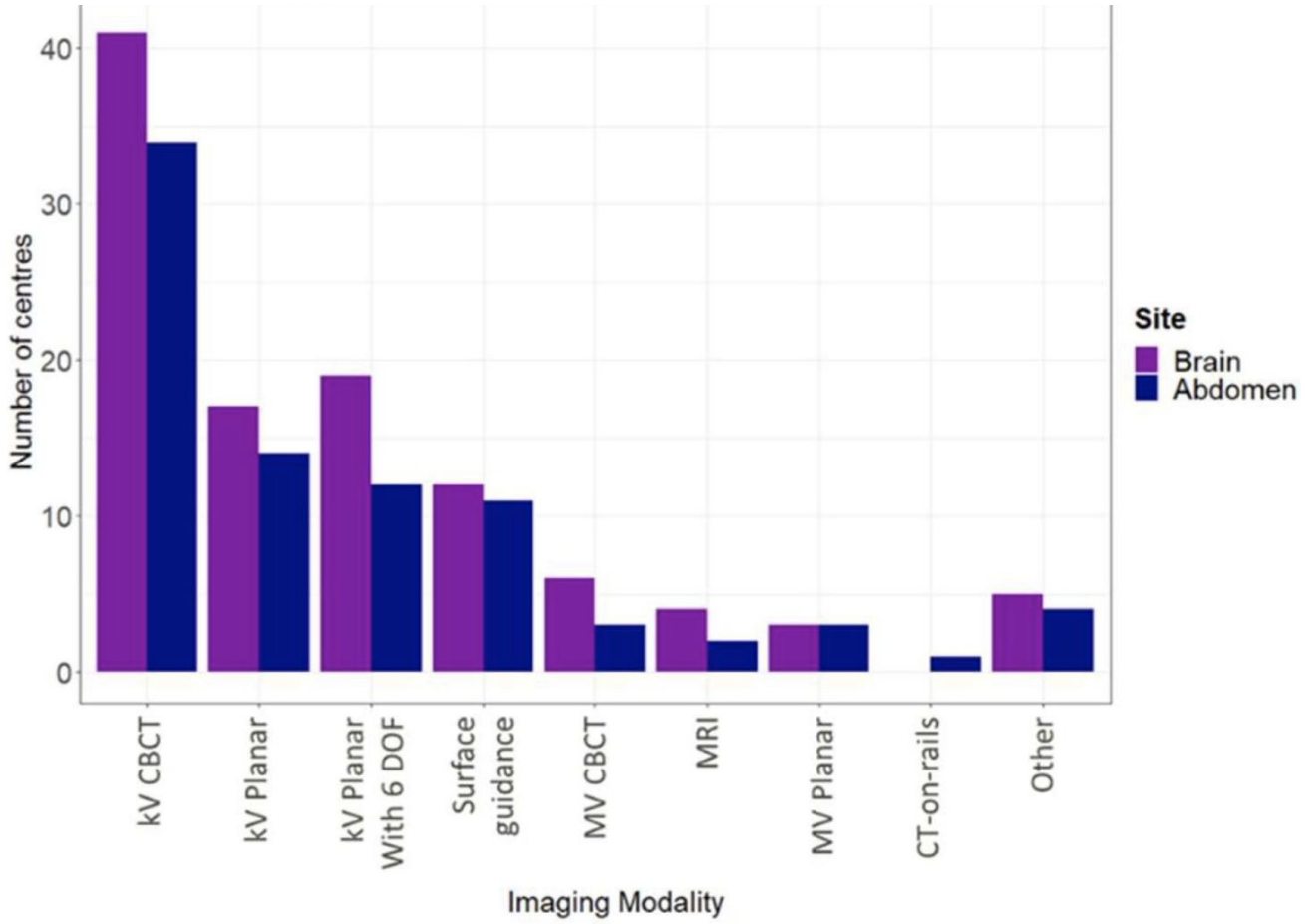
Survey SIOPE 2022

Responses:

50/246 Centers
25/35 European countries

Using kV CBCT as only imaging modality:

15/50 brain/head
13/50 abdomen



Survey SIOPE 2022
CBCT frequency

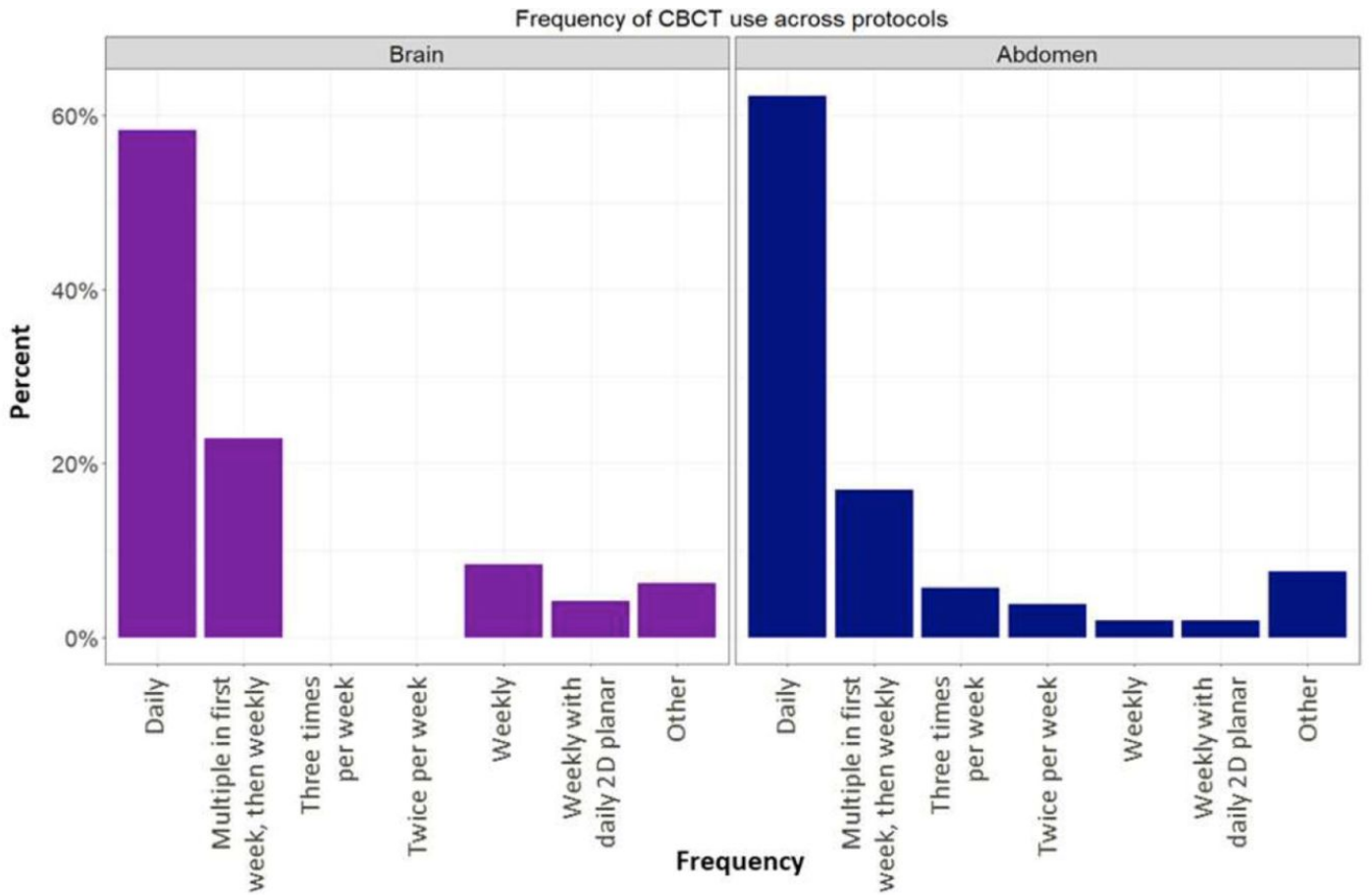
Technical settings:

Brain/head: 30/50 centres
Abdomen: 31/50 centres

Reported protocols:

Brain/head: 48
Abdomen: 53

Most protocols
Daily CBCT



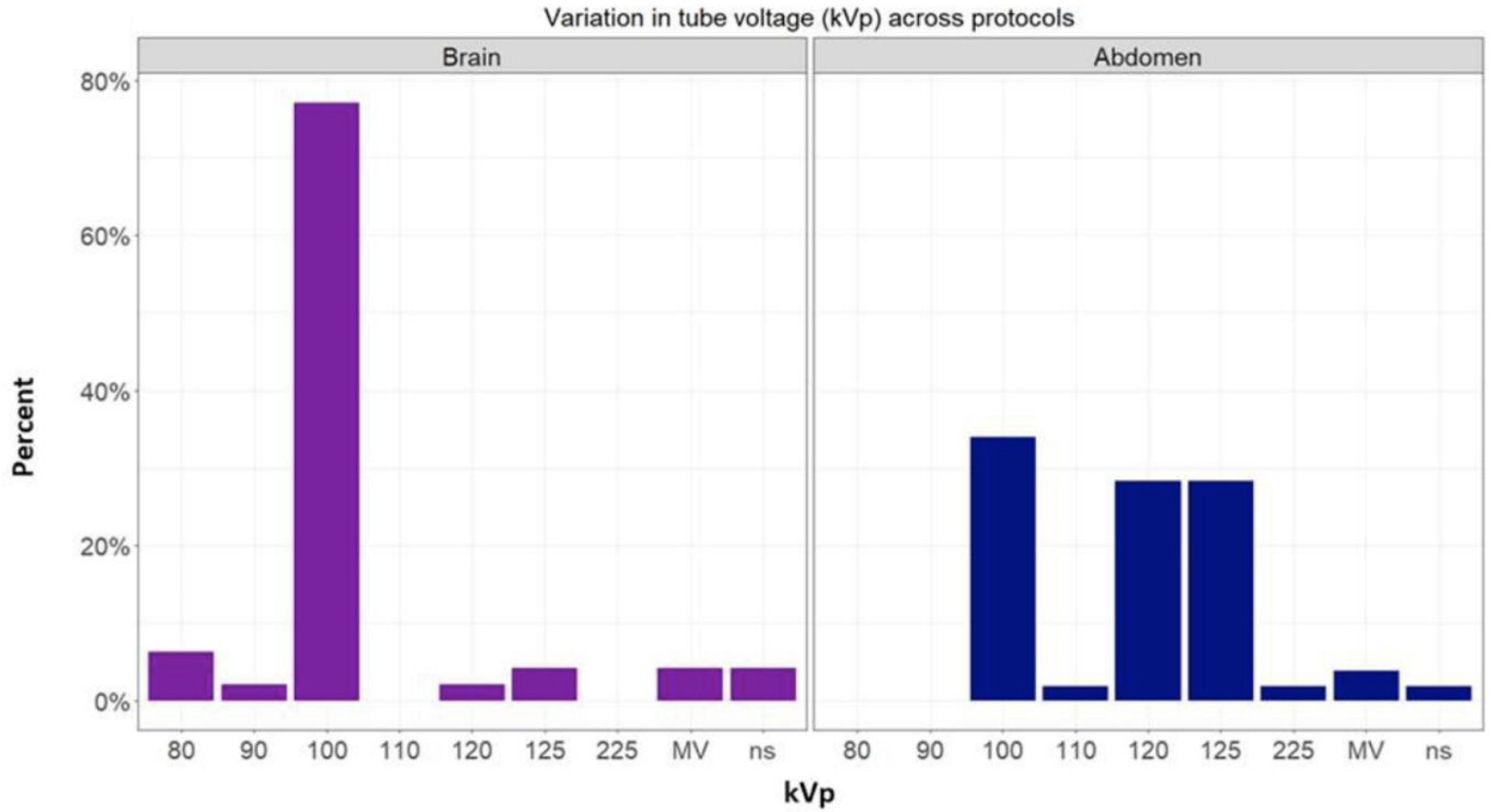
Survey SIOPE 2022
kVp

Technical settings:

Brain/head: 30/50 centres
Abdomen: 31/50 centres

Reported protocols:

Brain/head: 48
Abdomen: 53



High agreement for brain/head (100kVp)

Variability for abdomen

Survey SIOPE 2022
kVp

Reported protocols:

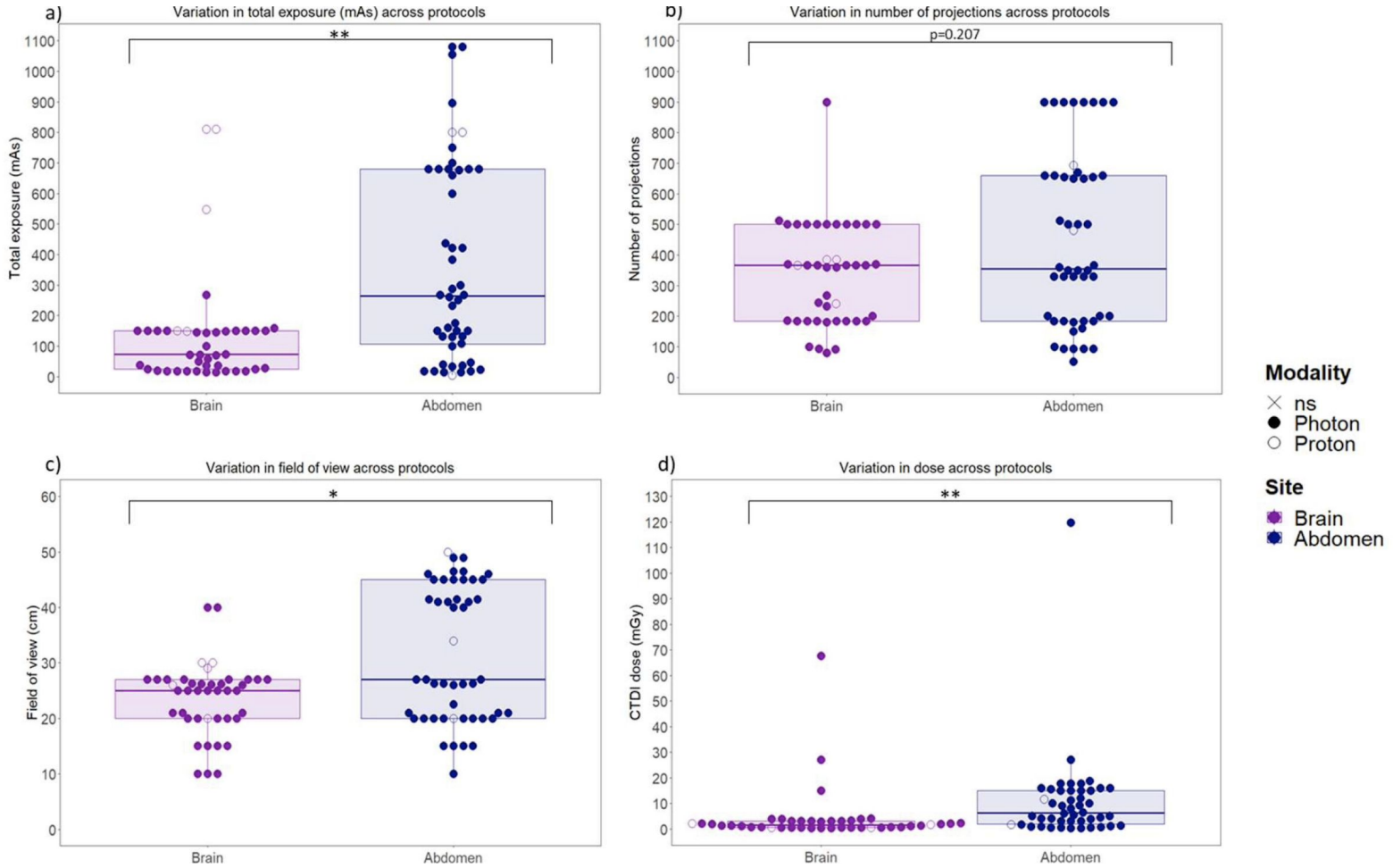
Brain/head: 48
Abdomen: 53

- Higher mAs abdominal protocols *p<0.001*
- Consistency number of projections between head and abdomen
- mAs and projection number moderate + correlation:
  - Head 0.20 mAs/projection
  - Abdomen 0.76 mAs /projection
- Dose optimization mAs rather than projection number
- Use of bowtie filters
  - Brain/Head

27 full-fan bowtie filters
3 half fan
16 no filter

  - Abdomen

22 used full-fan bowtie filters
17half fan
13 no filter



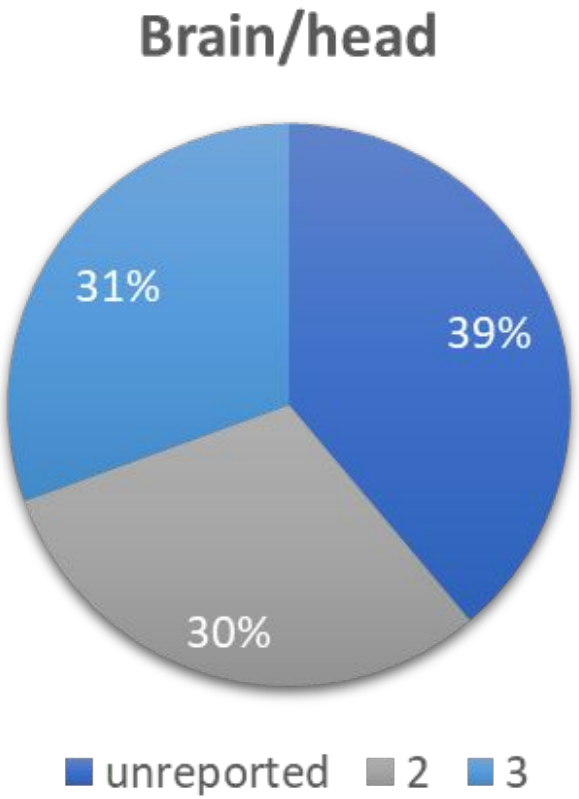
Survey SIOPE 2022
Dose

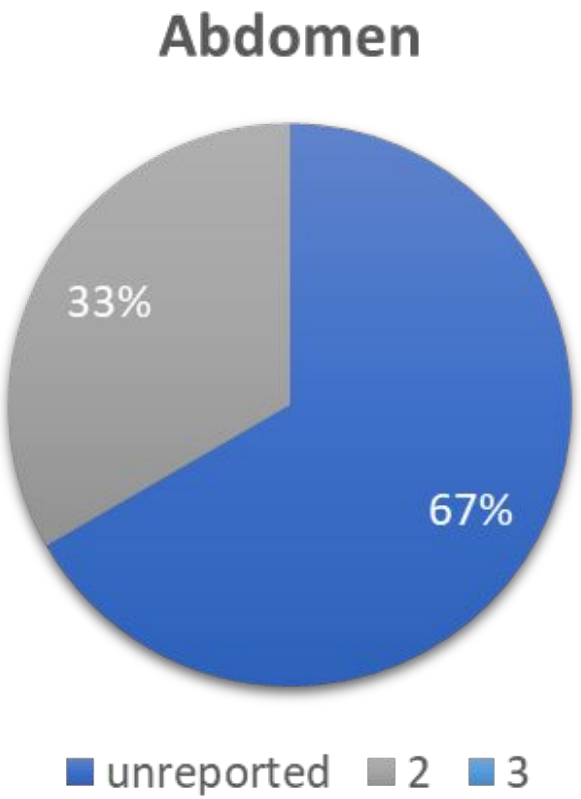
Table 2
Summary of exposure settings applied to achieve CBCT scans.

	No. protocols	kVp	mAs	No. projections	FOV
Brain/Head protocols					
0 ≤ 1 mGy	17	100 (100–100)	18.4 (18.0–42.1)	185 (183–366)	26.0 (20.0–27.0)
1 ≤ 2 mGy	10	100 (100–100)	71.0 (40.3–130.5)	369 (367–471)	26.0 (25.0–27.0)
2 ≤ 5 mGy	12	100 (100–100)	149.0 (144.8–150.0)	369 (198–500)	25.0 (21.0–26.1)
5 ≤ 10 mGy	0	–	–	–	–
≥10 mGy	1	100 (100–100)	150.0 (150.0–150.0)	500 (500–500)	10.0 (10.0–10.0)
Abdominal protocols					
0 ≤ 1 mGy	9	100 (100–100)	18.3 (18.0–33.0)	183 (180–330)	20.0 (20.0–21.0)
1 ≤ 2 mGy	3	100 (100–100)	108.0 (74.0–454.0)	693 (447–797)	38.5 (32.8–44.3)
2 ≤ 5 mGy	8	115 (100–120)	167.5 (150.0–252.5)	200 (143–538)	26.7 (25.0–32.0)
5 ≤ 10 mGy	9	120 (100–125)	361.0 (283.0–478.1)	367 (330–500)	33.7 (23.4–41.0)
≥10 mGy	15	125 (120–125)	680.0 (668.0–725.0)	655 (415–785)	45.0 (41.5–46.0)

Survey SIOPE 2022

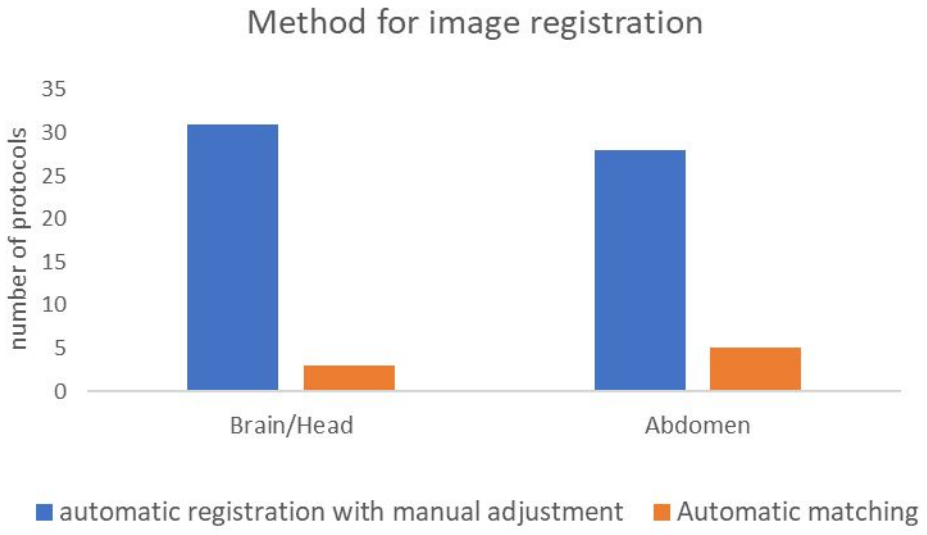
Image repetition

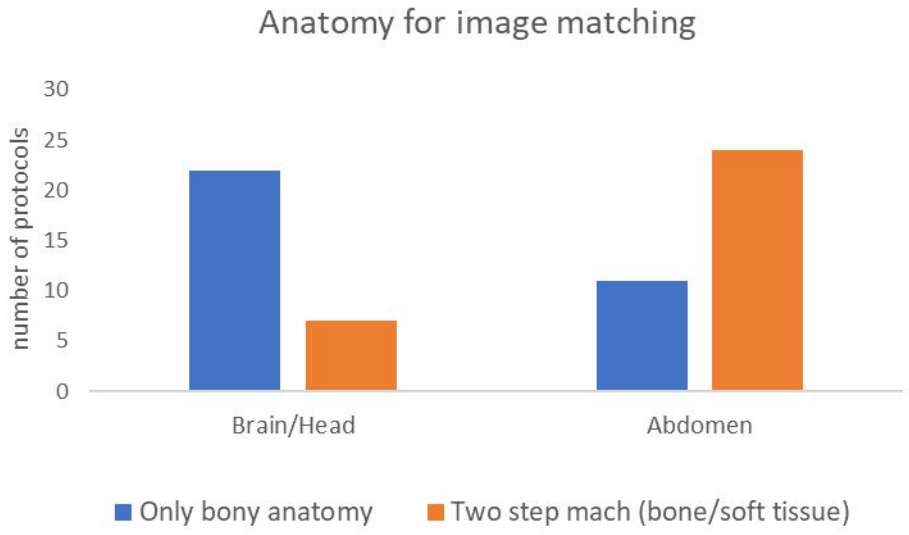




Survey SIOPE 2022

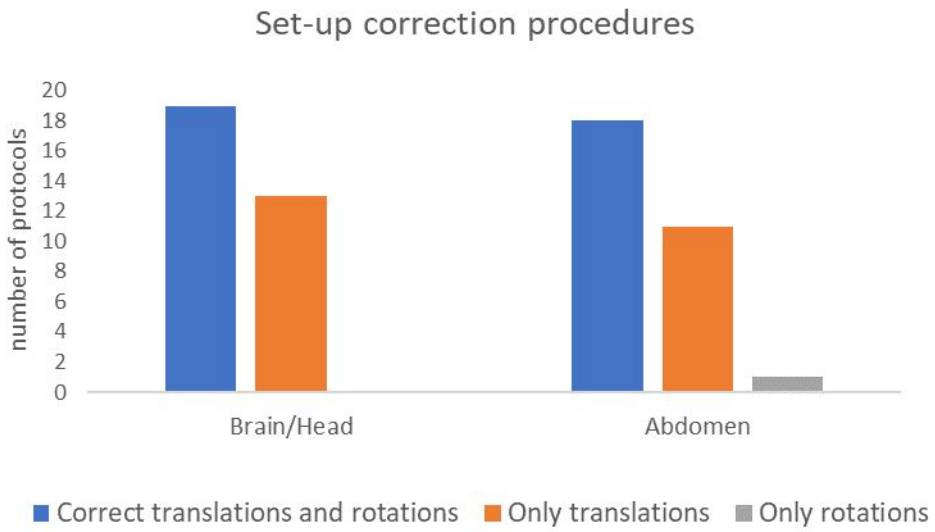
Set Up Protocols

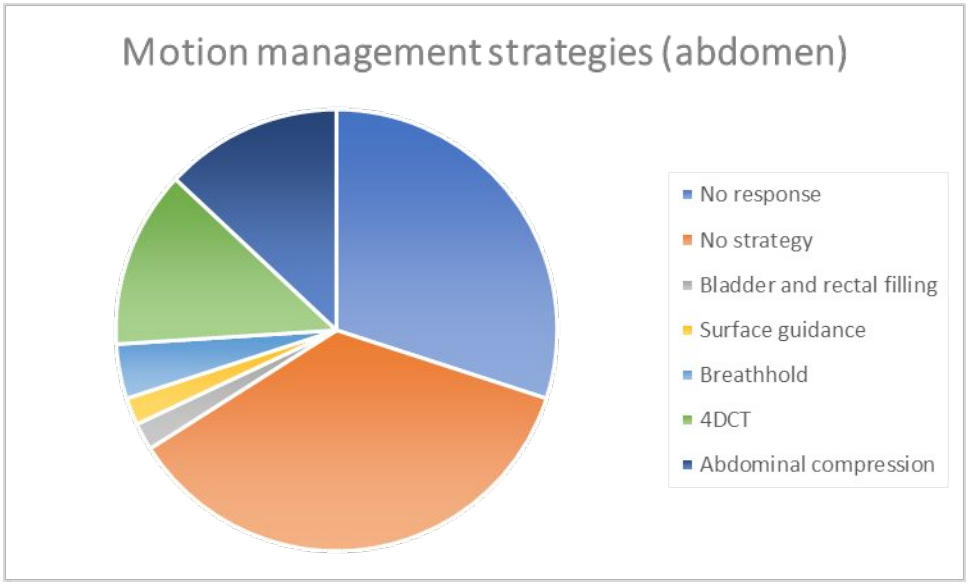




Survey SIOPE 2022

Set Up Protocols

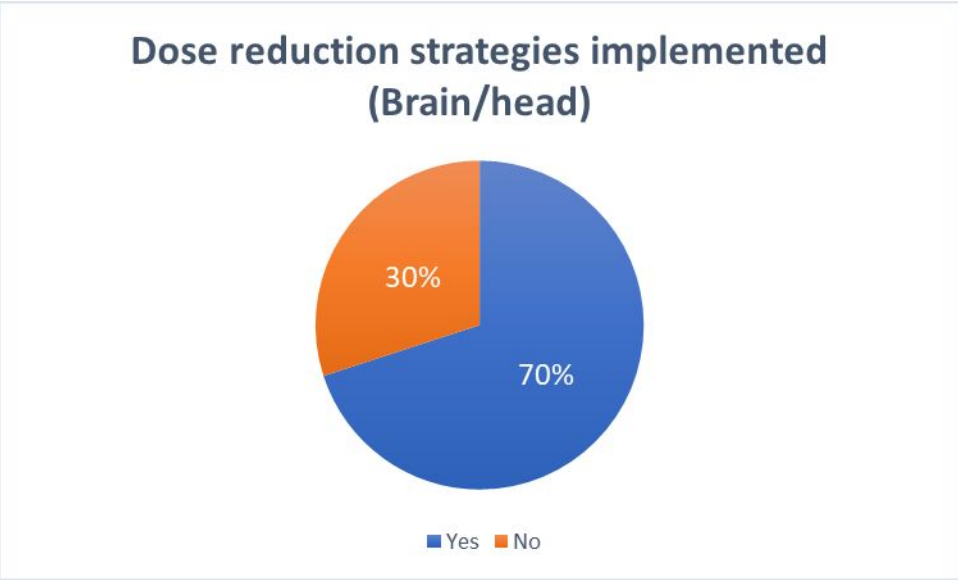


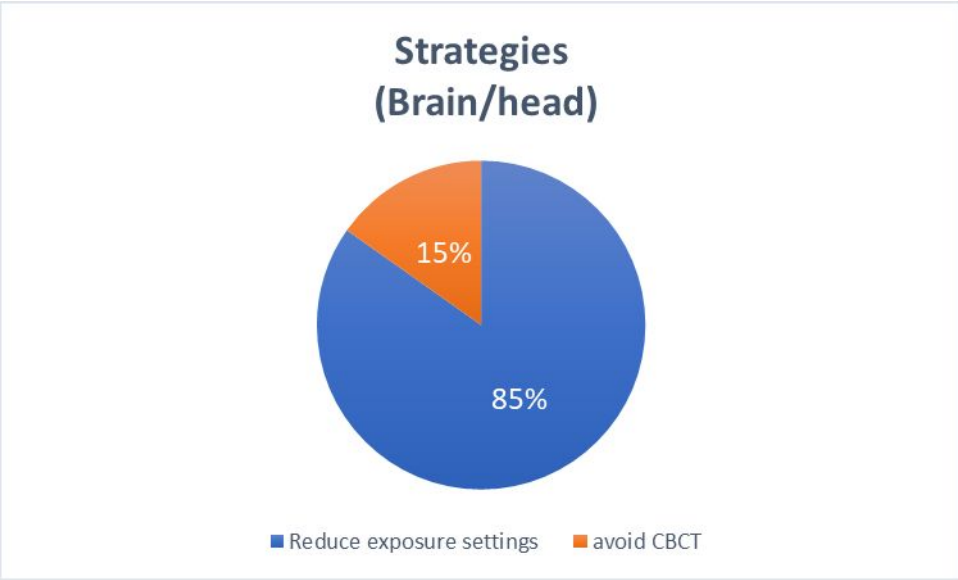


Site	Tolerance (translation)	Tolerance rotation
Brain/Head	1,5 mm (1-3)	1º (0,2-2,3)
Abdomen	1,5 mm (0,8-3)	1 (0,2-2,0)

Survey SIOPE 2022

Strategies to reduce dose





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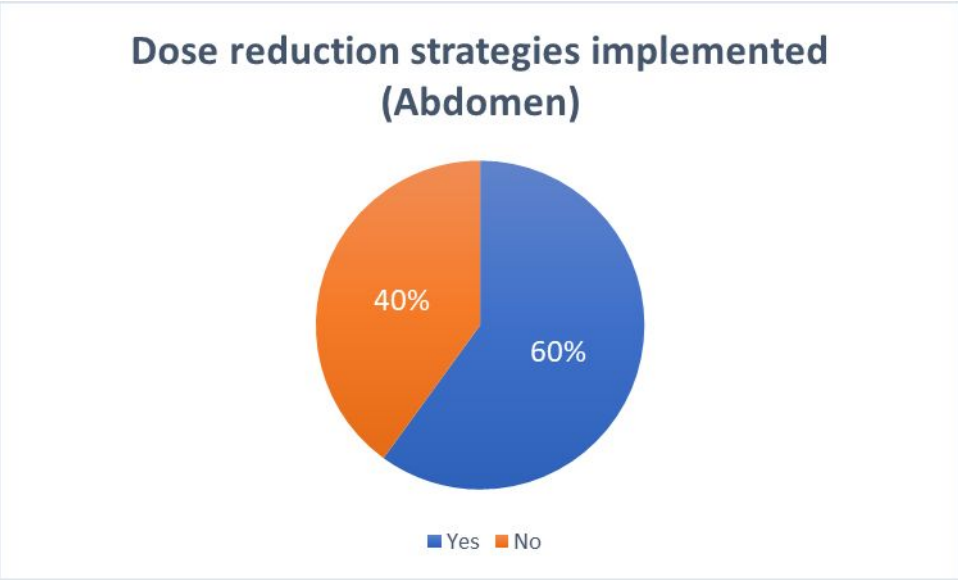
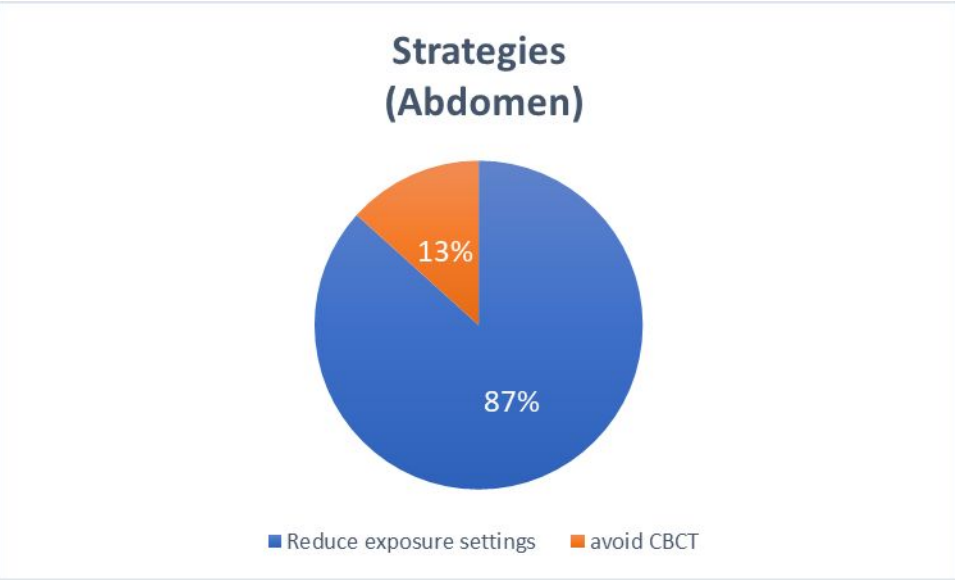
Strategies to reduce dose





Survey SIOPE 2022
Main findings

Daily CBCT is widely used

Large variation in technical acquisition parameters (more consistency for head/brain)

Although low-dose CBCT for IGRT is feasible for paediatric patients only 39% of surveyed centers have optimized CBCT

URGENT need FOR IMPLEMENTING optimizsed paediatric IGRT protocols.

Wrap up from the two surveys
Recommendations

From 2015 to 2022 increase of the use of daily CBCT

Still most of the centers have not optimized image protocols

The recommendations from 2015 survey still up-to-date:

- Exposure parameters adapted to size/weight (not only to age)
- Education to Radiation Oncologists and RTTs on dose optimisation in IGRT
- Need for consensus recommendations to guide clinical decision-making on optimal IGRT use for paediatric patients
- Need for guidelines for size specific dose optimization approaches

To be adapted for RT imaging

To be adapted for RT imaging