Development of an Age-Scalable Colon Model with Substructures for Colon Radiation Therapy Dosimetry in Large Pediatric Cohorts for Late-Effects Studies

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Introduction

Background

To date, radiation therapy (RT)-related late-effects studies with colorectum have included prescribed pelvic dose or estimated the proximity of specific colorectal parts to the RT field, but have not included mean RT dose to the whole colorectum, substructure doses or dose-volume metrics.

Clinical Impact

Incorporation of colon-specific dosimetry could lead to more meaningful dose-response models that could:

- Better inform survivorship care plans
- Define colon and substructure dose constraints for RT treatment planning

Purpose

To develop a detailed age-scalable colon model with substructures for our in-house late effects computational phantom, which will allow calculation of these additional RT dose metrics for future studies on second colorectal cancers in childhood cancer survivors.

1 Materials

NCI Colorectal Model Background

- We used 6 whole-body CT-based phantoms (ages: 0.1, 1, 5, 10, 15 and 30 years) from the National Cancer Institute (NCI) computational human phantom series; each of which has a delineated colon with substructures.
- Since these phantoms are only available for select ages, we integrated the NCI colons into our in-house phantom which can be scaled to any age (infant-to-adult).

Dataset

- 6 colorectal models from whole-body CT-based computational phantoms from the NCI.
  - > Ages: 6 days, 1, 5, 10, 15 and 20 years
- Our in-house computational phantom which can be scaled to any age from infant to adult.
  - > Our age-based scaling method is based on growth data of over 4000 children (Snyder et al., 1977).

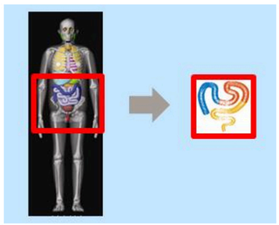
2 Methods

Methodology

- The following steps were performed to register and integrate the NCI colorectal models into our in-house computational phantom.
- Each step was repeated 6 times, once for each age-specific colorectal model.

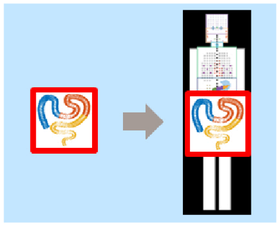
Step A

- First, we extracted the colorectum model from each NCI computational phantom.



Step B

- Second, we rigidly registered each extracted colorectal model with our same-age in-house computational phantom.



Step C

- Third, we created an age-based colon model selection process, whereby for a given individual, the colon model that is the closest in age is selected and scaled to their age at RT.
- *Note: Age-scaling is used because height and weight are not generally available in historic RT records.*

3 Results

- We successfully integrated six anatomically realistic CT-based colon models with substructures from an international phantom reference library into our in-house computational phantom.
- Uniquely, these colon models can be scaled to any age at RT.

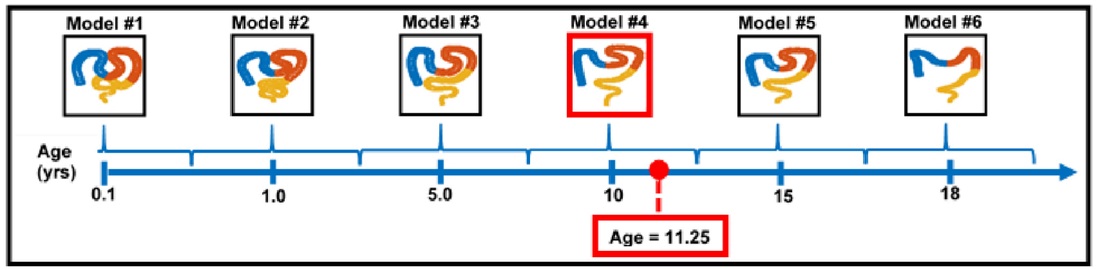


Figure 1. Selection of Colorectal Model for Scaling Colorectal Model to Age at RT. Six different colorectal models were integrated into our in-house computational phantom; one for each select age of the NCI phantom series. The midpoint between select ages will determine the colon model to be used for scaling to other ages. For example, to extract and scale a colorectum for a patient that received RT at age 11.25 years, colorectum model #4 would be selected. Since colorectum model #4 is based on anatomy of a 10-year-old, the colorectal model would be scaled up to adequately represent the colorectum size for a patient of age 11.25 years.

4 Conclusion

- We now have the capability to perform colorectum and colon substructure RT dosimetry for a study on RT-related late-effects in childhood cancer survivors.
- Incorporation of this detailed colon dosimetry could lead to more meaningful dose-response models that could be used to better inform survivorship care plans.

5 Future Directions

- This colorectal model will be used to perform colorectal dosimetry on 13,000+ survivors of childhood cancer that were treated with RT, but whose RT treatment planning generally was not CT-based.
- We will investigate the relationship between colorectal- and substructure-specific RT dose metrics (e.g., RT mean dose and dose-volume metrics) and colorectal SMN risk.
- Several dose-volume metrics will be explored. For example, we will compute the volume of whole colon receiving 5 Gy. Dose-volume metrics for each colon substructure will also be evaluated.

6 References

- Snyder, R.G., Schneider, L.W., Owings, et. al., 1977. Anthropometry of infants, children and youths to age 18 for product safety design SP-450. Society of Automotive Engineers, Warrendale, Pa.

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