Age-Dependent Skeletal Tissue Models for the UF/MSK Newborn, Infant, Toddler Phantom Series

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Introduction

The number of computed tomography (CT) scans performed on pediatric patients in the US is estimated to be between 5 and 9 million each year. The more rapidly dividing and undifferentiated cells of this age group make them especially vulnerable to the effects of ionizing radiation, so it is critical to have accurate dose tracking for risk-based decision making in the clinic. The use of computational phantoms allows for organ dose estimation through Monte Carlo (MC) radiation transport simulations, but the current base of pediatric phantoms is limited. This dose library forms the basis for fast calculation of patient-dependent cumulative organ doses for a range of clinical protocols.

Methodology

- The 0- and 1-year-old male and female mesh-type reference phantoms (MRCPs) from ICRP 156 (2025) have been scaled to match height, head circumference, and mass targets taken from CDC population survey data
- Skeletal tissue material compositions have been updated to account for age-dependent bone volume fractions, including red bone marrow and endosteum
- Monte Carlo radiation transport simulations have been conduction on each phantom using the Particle and Heavy Ion Transport code System (PHITS)
- Simulations are performed at using a wide range of technique factors such as bowtie filter size, kVp, and collimated beam width to represent clinical CT scan protocols
- Organ dose data is then incorporated into MIRDct, which incorporates differences between scanner vendors and models, and accounts for the impact of tube current modulation (TCM)

Results

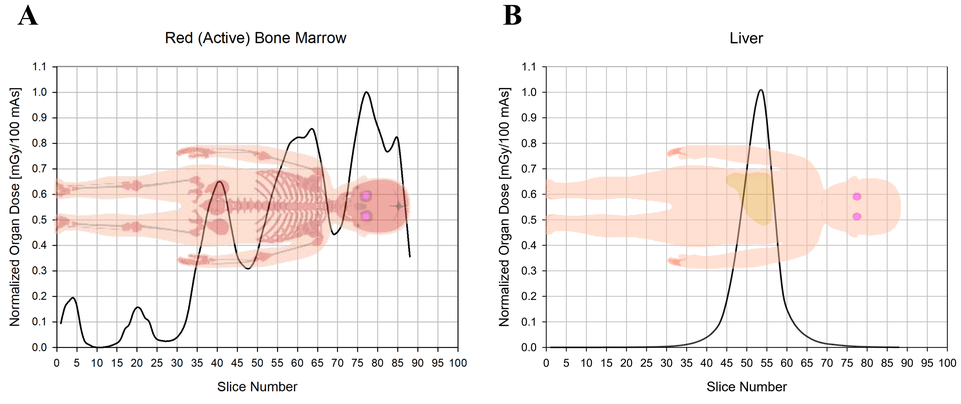

Figure 1: Dose profiles for (A) red/active bone marrow and (B) the liver displayed in normalized dose per slice number. The phantom used in the 24-month-old female NIT phantom at 50th percentile height, weight, and head circumference.

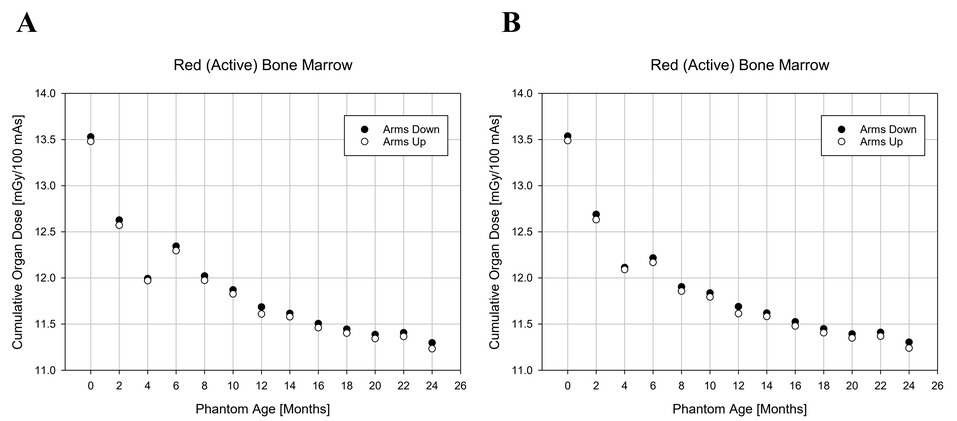

Figure 2: Comparison of dose trends by age across the phantom library for (A) red/active bone marrow before skeletal tissue update (B) after skeletal tissue update in cumulative organ dose per phantom age for the arms-up and arms-down sections.

Conclusion

A total of 59 unique target metric combinations were used to create a library of 236 NIT phantoms (including both male and female as well as arms-down and arms-up versions). Phantoms are arranged by age from 0 to 2 years at 2-month increments, and height/weight groups of 10th, 50th, and 90th percentile. An extended section of the phantom library with a wider range of height/weight combinations has also been developed. Skeletal tissues have been updated to better account for changing bone volume fractions in these age groups. Monte Carlo simulations have been completed and cumulative organ dose values for a given scan length have been calculated using the available technique factors as well as tube current and table pitch.

Future Work

- Completion of organ dose library on extended collection of height/weight combinations
- Integration of organ dose library into the freely-available Excel-based dosimetry platform MIRDct at MIRDsoft.org

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