Purpose: To estimate the accuracy of whole-body computational phantoms for patient specific out-of-field dosimetry in secondary cancer risk assessment following proton radiotherapy when a whole-body CT is not available.

Methods: Computational human phantoms were used in a benchmarked GEANT4-based Monte Carlo code to calculate doses for several radiosensitive organs such as brain, thyroid, lungs, bronchi and esophagus. Six pediatric patients, ages 4 to 14, with available whole-body CT scans were considered. Standard reference voxelized (UFB) phantoms and a series of new and flexible pediatric phantoms known as the reference hybrid (RH) phantoms were applied and organ doses were calculated and compared with the ones from the patient specific CT. The accuracy of the RH phantoms was further examined by sculpting these models according to the patient specific heights and weights, making them partly patient specific. Circular 3cm-diameter proton fields were used to irradiate the cranium and the spine of all phantoms with 90 and 180-degree gantry angles respectively. Protons and neutrons exiting the treatment head were transported in the phantom geometry separately in order to differentiate between doses from external and internal neutrons, which were added for the final dose.

Results: The percent differences between UFB/CT, RH/CT and SH/CT phantom dose ratios and unity, were much smaller in hybrid phantoms compared to the UFB ones for the subjects and organs of study. In case of thyroid of a 14-year-old subject, for instance, the improvement was approximately a factor of 15. The effect of sculpting the RH phantoms depended on the organ and patient stature.

Conclusions: For estimating organ doses from scattered radiation in radiotherapy, commonly used standard whole-body computational phantoms might not be sufficient. Hybrid reference phantoms or patient-sculpted reference phantoms represent the actual patient geometry more precisely and yield more reliable organ doses for secondary cancer risk calculations.