APPLYING LESSONS LEARNED FROM CLINICAL RADIOTHERAPY TO IMPROVE BIOPHYSICAL MODELING OF CLINICAL OUTCOMES USED TO GUIDE MANAGEMENT AND COUNTERMEASURES FOLLOWING ACUTE RADIATION EXPOSURES

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Astronauts traveling outside of the protection afforded by the Earth's magnetosphere are subjected to the increased risk of radiation exposure from Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE). In the event of an acute radiation exposure, rapid assessment of the risk posed to astronauts will require accurate estimate of dose distributions for each astronaut. For higher energy particles contained in galactic cosmic rays, the individual variation in astronaut anatomy is unlikely to alter the dose distribution within each astronaut and the inter-astronaut variability would therefore be small. However due to the lower but highly variable energy spectrum of SPE particles and the variables of shielding and angular distribution of particles, individual astronaut anatomy may contribute to variability in the resulting dose distribution. In addition, understanding what the measured energy spectrum and fluence anisotropy of an ongoing SPE does to the dose distribution may be critical in prescribing countermeasures and in adaptation of mission planning.

The National Space Biomedical Research Institute (NSBRI) Center for Acute Radiation Research (CARR) has been developing an integrated, systems based approach to reproducing radiation exposures in animal models to improve the clinical utility of radiation toxicity predictions and treatment recommendations for Astronauts exposed to solar particle event (SPE) radiation. In support of this approach, we have previously developed and evaluated a dosimetry modeling package that adapts clinical radiotherapy treatment planning techniques to model SPE-like radiation dose distributions in experimental animals. In the present work, we have modified and evaluated the current dosimetry modeling package to assess the relative contributions to organ dose from individual variations in SPE energy/fluence profile and human anatomic variability.

We used 10 full body human CT scans (5 male and 5 female) and simulated exposure with EVA or spacecraft shielding levels for the August 1972, September 1989 and October 1989 SPE. When we examined the SPE energy/fluence profile dependence for dose to superficial organs such as skin, the dose variation for different humans was much less pronounced than the dose variation due to SPE identity. However, for deeper organs, such as lungs, marrow or stomach, the individual variations in human anatomy/morphology led to significant overlap between organ doses for different events. This preliminary analysis suggests that for superficial organs, the specific SPE dominates the organ dosimetry, while for deeper/more internal organs, the individual variation in astronaut anatomy/morphology appear to be more important for organ dosimetry than the specific SPE. To further explore this hypothesis, we have quantitatively analyzed differences in organ dosimetry parameters between humans for different SPE. This analysis demonstrates that there is a significant difference for internal organ doses of males vs females. However, even within the same gender, individual anatomical variation led to significant differences in organ dosimetry for the same event. We have also investigated which specific anatomical parameters lead to these variations between genders or between individuals of the same gender, examining multiple parameters including height, weight, body mass index, waist circumference and percent body fat. This analysis is ongoing, but thus far, waist circumference appears to be a potential surrogate that would allow for rapid scaling and personalization of the dose for a specific astronaut without the need to run a lengthy computer simulation. We are continuing to analyze these parameters with the goal of developing a tool that would allow rapid assessment of dose for any given individual based solely on a simplified set of anatomical, shielding and energy/fluence data. Finally, to begin developing a personalized and dose specific clinical decision-making tool, we are combining dosimetry and physiologic data from animal model experiments and clinical (human) exposure scenarios with the goal of being able to rapidly assess organ doses for clinical outcome predictions.

Acknowledgements: This research is supported by the NSBRI Center of Acute Radiation Research (CARR) grant; NSBRI is funded through NASA NCC 9-58.