Beagle dog mesh-type computational phantoms for preclinical radionuclide dosimetry

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Introduction

Between 1952 and 1991 inhalation studies of radionuclides were performed using beagle dogs. The goal of these experiments was to study the effect of nuclear debris from the fission products of U-235 which would be critical information to aid exposed military and civilian personnel in the event of a nuclear bomb detonation. The radiation exposure consisted of chronic gamma irradiation as well as more intense fractionated exposure which led to the development of fibrosus and/or lung cancer in the exposed canines. Tissues were collected after the time of death and research concerning distribution, retention and the health effects of these dogs are currently being performed, but dosimetry studies to correlate these health effects to radiation doses need to be completed. Creating a tetrahedral mesh phantom of a beagle dog allows computationally efficient and accurate Monte Carlo dose computations for correlation to these studies.

Methodology

Cross-sectional photographs of a frozen female beagle, generated using methods analogous to those used in the Visible Human Project, were imported into 3D Slicer software and manually segmented to delineate the different tissue regions. Contours were then converted into polygon mesh format and iteratively refined in Blender software. For the male model, CT images were used to construct meshes representing testis and prostate, which then replaced the corresponding sex-specific organs in the female model. A blood volume distribution model was developed and used to calculate tissue densities and tissue elemental compositions. Models were converted into tetrahedral mesh format and used to perform MC simulations in PHITS to obtain SAFs and S-values.

Results

Male and female computational beagle phantoms were constructed in high-quality mesh format, featuring a detail skeletal model. MC radiation transport simulations were performed to compute SAFs and S-values for all source-target organ combinations for a variety of radionuclides relevant to preclinical dosimetry studies.

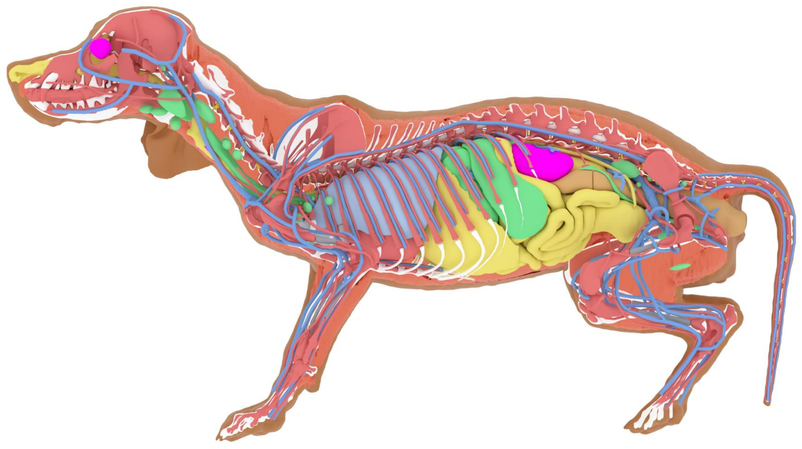


Figure 1. Sagittal view of the female beagle mesh-type phantom.

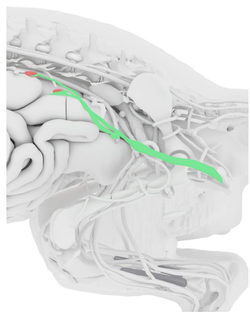


Figure 2. Sagittal view of the female phantom. Uterus is shown in green and ovaries in pink.

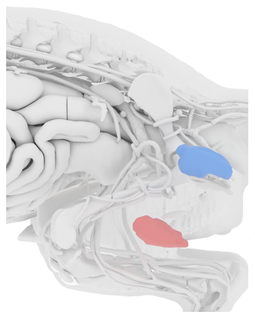


Figure 3. Sagittal view of the male phantom. Prostate is shown in blue and testis in pink.

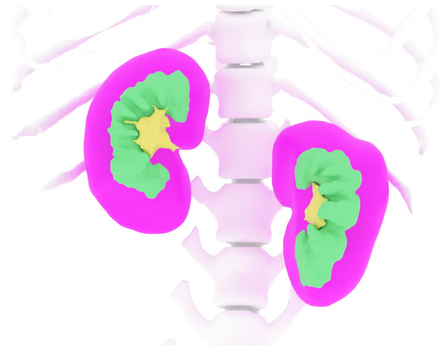
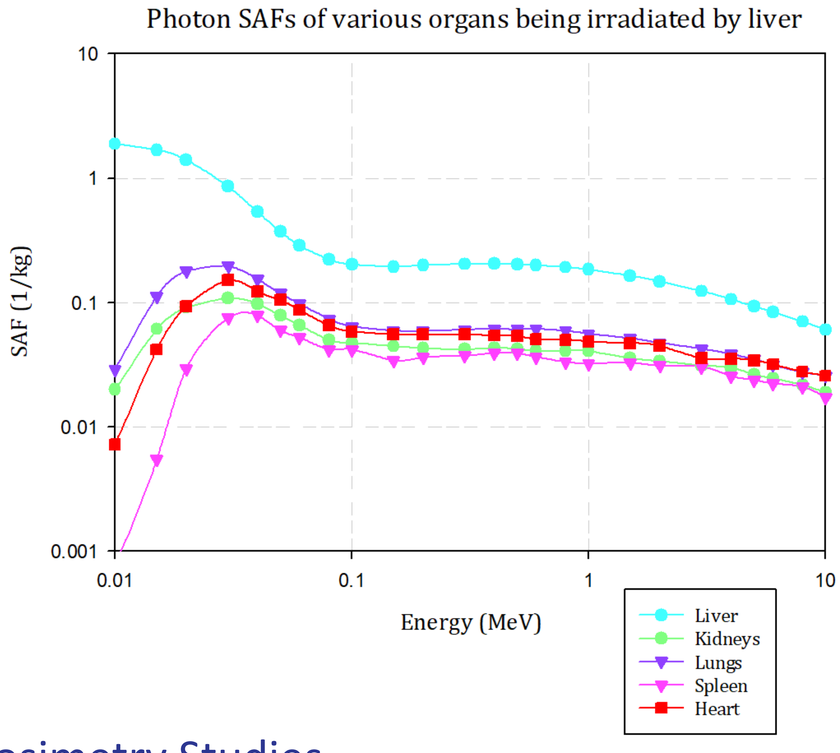


Figure 4. Ventrodorsal view of the kidneys. Medulla (green) and renal pelvis (yellow) regions are shown inside the cortex (magenta).



Conclusions

The computational beagle phantoms developed in this study have a variety of potential uses, particularly in the context of in-silico, preclinical dosimetry studies exploring the effects of radionuclide therapies.
These canine phantoms will include a skeletal microstructure model that allows the estimation of red bone marrow and endosteum dose.

Future Work

- Values for trabecular volume fraction, trabecular number and cellularity factor will be used along human microCT spongiosa images and an in-house bone generator code to create microscale skeletal models to better estimate radiation doses due to short range particles such as alpha radiation to the active bone marrow
- These phantoms will be implemented into the MIRDcalc software, a software that estimates organ doses based on the time integrated activity coefficient of various organs, which currently can only be used in human male and female phantoms.

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