



# Validation of Particle and Heavy Ion Transport Code System (PHITS) in generating dose–voxel kernels for internal dosimetry calculations

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## Abstract

### Purpose

In voxel-based dosimetry, dose–voxel kernels (DVKs) represent the absorbed dose in a target voxel per decay in a source voxel. In this work, we aimed to validate DVKs generated using Particle and Heavy Ion Transport Code System (PHITS) as a first step in establishing a quantitative SPECT/CT-based dosimetry framework for selective internal radiation therapy (SIRT).

### Methods

A 1-MBq source of  $^{90}\text{Y}$ ,  $^{153}\text{Sm}$ ,  $^{177}\text{Lu}$ ,  $^{188}\text{Re}$ , and  $^{166}\text{Ho}$  located in central cubic voxels of 1 mm, 3 mm, and 6 mm dimension within soft tissue ( $1.04\text{ g}\cdot\text{cm}^{-3}$ ), was simulated using  $2.5 \times 10^7$  histories in PHITS. The DVK results were compared to published data (Lanconelli et al., 2012). In a pilot study, 17 MBq of  $^{153}\text{Sm}$  microspheres were injected into a liver tumor-bearing rat and imaged 24 h later using SPECT/CT. SPECT/CT images were then converted to cumulated activity and convolved with a  $^{153}\text{Sm}$  DVK using Fast Fourier Transform in MATLAB to create an absorbed dose map.

### Results

As expected, DVKs for the radionuclides showed a steep decrease from the source voxel to the maximum continuous slowing down approximation (CSDA) of beta components. Beyond the CSDA, gamma and bremsstrahlung contributed minimally ( $10^{-6}$  to  $10^{-4}$ ) to voxel doses. Observed DVK changes as voxel size increased were in good agreement with published data, with differences in source voxel ranging from 1 to 24%. Rat imaging revealed  $^{153}\text{Sm}$  microspheres localized at injection sites, with mean and maximum doses of 45 Gy and 194 Gy, respectively.

### Conclusion

The DVKs calculated in PHITS were successfully validated.  $^{153}\text{Sm}$  dose maps were produced from SPECT/CT images in a rat model. Further studies on the application of DVKs in heterogeneous media will be conducted.