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Monte Carlo based System Matrix calculation for iterative reconstruction in X-ray Luminescence Optical Tomography

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X-ray luminescence optical tomography (XLOT) has been proposed to study problems related to deep-tissue small-animal imaging. In this technique, luminescent nanoparticles emit optical photons when irradiated with a collimated x-ray beam. The use of this modality for small-animal imaging requires an accurate knowledge of the energy deposition map inside the subject for optimization of the optical imaging model used in the tomographic reconstruction. It is of interest to determine the contribution of scattered radiation to the luminescent signal, since this might limit the spatial and contrast resolution of the system. In this work, we report the use of Monte Carlo simulation for the calculation of a system response matrix including attenuation and scatter effects in mouse size phantoms with embedded Gd2O2S inserts using a W target x-ray tube in the range of 30-90 kVp with an added 1.0 mm Al filtration.
The results show that the scatter contribution is of the order of 25% of the total dose to the insert and that it scales linearly with kVp for a fixed concentration (1 mg/ml) of luminescent nanoparticles at a fixed air-kerma rate. The imaging performance of the system was evaluated by means of simulations of the NEMA NU4 image quality and micro-Derenzo phantoms. The results show that quantification of the luminescent particle concentration deteriorates with object size, up to 80% when going from 5 to 1 mm diameter objects at 1 mg/ml concentration. The optical spatial resolution with 0.5 mm step size and 5 degrees' angular sampling is of the order of 0.8 mm using the MLEM reconstruction algorithm.
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