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Assessing the feasibility of high-Z metal (oxide) nanoparticles as contrast enhancement agents in proton imaging for a small animal irradiation platform

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Introduction

With increasing number of proton therapy facilities, proton imaging is becoming more relevant. It allows to directly reconstruct the relative (to water) stopping power (RSP), reducing range uncertainties in treatment planning. Tumour visualization can be improved by contrast enhancement, however little research is available about contrast agents for proton imaging. Our study assesses the feasibility of high-Z metal-(oxide) nanoparticles as contrast agents for proton imaging.

Materials & Methods

A FLUKA Monte Carlo simulation framework of a pre-clinical proton computed tomography (pCT) system [1] was used to evaluate the potential of contrast enhancement by gold, gadolinium(III)- and bismuth(III)-oxide nanoparticles. A cylindrical water phantom containing inserts (4mm diameter) with varying concentrations of homogeneously distributed metal-(oxide), mimicking the nanoparticles, was considered for imaging. To complement simulations, proton radiographies were taken at a clinical proton therapy facility using a miniaturized Timepix detector behind a 2cm thick PMMA block with insert (1cm diameter), filled with oil-gadolinium(III)-oxide nanoparticles solutions of varying concentrations.

Results

In simulated pCT images, notable contrast enhancement was observed at 4%wt for all three nanoparticles, with contrast-to-noise ratios between 2.2 and 2.7 (figure 1). Water equivalent thickness (WET) profiles of experimental radiographies (figure 2) indicate that contrast enhancement can be observed already with 4%wt gadolium(III)-oxide nanoparticles, supporting simulation results.

Conclusion

The feasibility of using gadolinium(III)-, bismuth(III)-oxide and gold nanoparticles as contrast agents in proton imaging has been tested in simulation and experimental (gadolinium only) studies. With already an appreciable contrast enhancement at 4%wt, these nanoparticles may provide a viable way to enhance tumor visibility in proton imaging.

Attachments

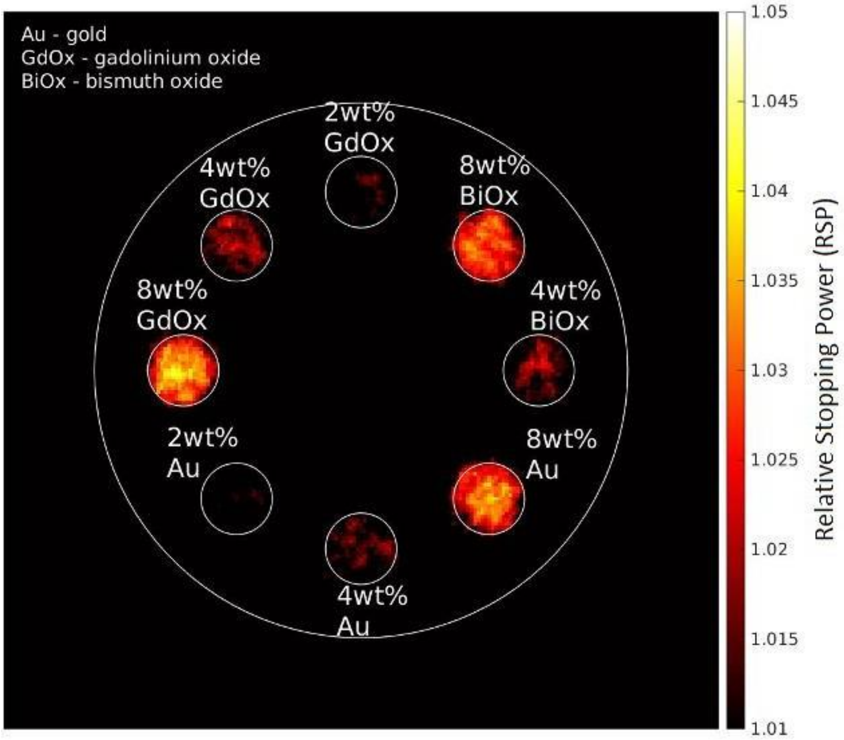

Figure 1: Reconstructed pCT image with various nanoparticle inserts.

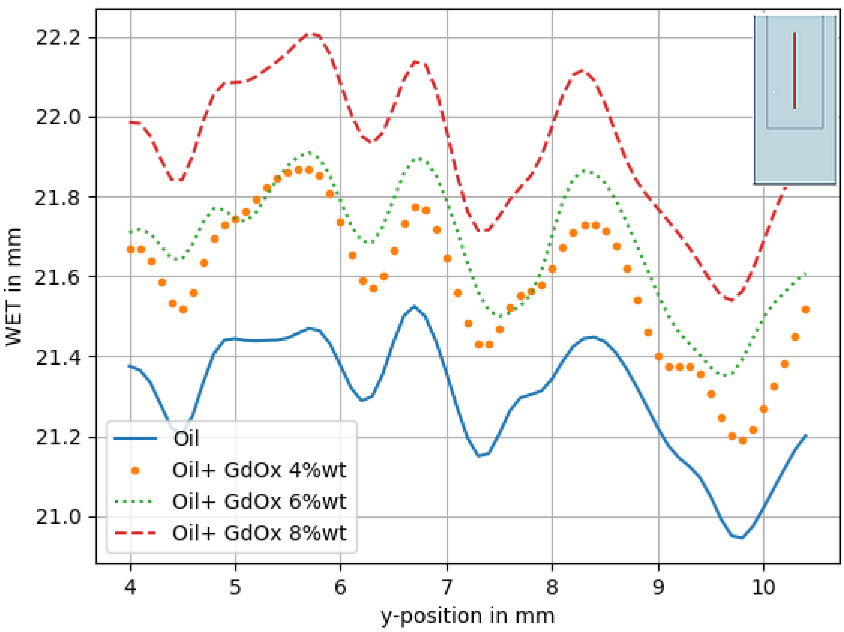

Figure 2: Experimental proton radiography WET profiles. The inset illustrates the block phantom, where the red line indicates profile's position.

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Literature

[1] Meyer et al., (2020). *PMB*