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Enhanced Positronium formation and Annihilation Localization with nano-scale magnetization

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Developments in radiolabeling superparamagnetic iron oxide nanoparticle (SPIONs) have gained increasing attention for cancer theranostic applications1. In a previous study, we demonstrated that the FDA approved SPION Feraheme® (FH) can be radiolabeled with a range of therapeutic and diagnostic isotopes: 64,67Cu, 90Y, 177Lu, 89Sr, 140Ba, 99Mo, 212Pb, 213Bi, 111In, 153Sm, 161Tb, 156,157Eu by the chelate-free heat induced radiolabeling technique2. In separate studies, we also demonstrated that radiolabeled FH can enhance dose deposition3 and that 89Zr-FH is a highly suitable radio-nanoplatform for hybrid PET- MR imaging4. Here, we investigate for the first time the effect of magnetized radiolabeled FH SPIONs on dose localization and positron range, as well as and ortho-positronium production from 89Zr-FH.

A series of [Fe] dilutions of 89Zr-FH samples was prepared in 10 separate phantom vials (including only 89Zr). The activity in each phantom was kept constant, A0 = 3.7 kBq. The phantoms were scanned using a simultaneous clinical PET-MR scanner (3T Biograph mMR). The full width at half maximum of the line spread function were calculated for the PET image data to assess the impact of magnetized FH SPIONs on the spatial resolution. The integrated standard value uptake for a circular region of interest for each phantom scan was calculated to quantify the dose localization.

Results demonstrated the magnetized FH SPIONs improved the spatial resolution of the 89Zr-FH phantom PET images by ≈ 17± 1.6 %, localized the dose by ≈ 40 ± 0.9 % and increased the true and random counts by ≈ 6% and 1% respectively, at a clinical [Fe] FH dose level. Both improvements in spatial resolution and dose localization are due to the nano-scale enhanced magnetic field induced by magnetized FH SPIONs and this has been further confirmed by PET-MR image analysis. In a clinical scenario, enhancing dose localization by 40% may improve the tumor control probability by 40%. Furthermore, the increase in true and random counts may be due to the interaction of positrons within the 89Zr-FH solution resulting in annihilation via formation of ortho-positronium (in the triplet state, 3S1) and emission of three gammas. Thus, this study further suggests radiolabeled SPION can enhance the production of ortho-positronium. Such triple-coincidences may be processed as a set of double coincidence events by the PET scanner. It would be interesting to follow up our study using emerging total body PET scanners, which with their superior sensitivity and 4π geometry are ideal for triple coincidence detection and potentially for ortho-positronium emission tomography.

Reference:
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