

Advanced Nanomaterials for Medical Imaging and Particle Tracking applications

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Abstract

Nanomaterials offer unique physical, chemical and biological properties of interest for medical imaging [1]. Among the various imaging modalities, positron emission tomography (PET) and magnetic resonance imaging (MRI) stand out for their exceptional sensitivity and spatial resolution, respectively (Figure 1A) [2]. Through the use of radiolabelled nanomaterials, it becomes possible to conduct thorough *in vivo* assessments of nanoparticle pharmacokinetics, while MRI delivers precise anatomical insights. Furthermore, nanomaterials present a high surface-to-volume ratio, enabling them to carry a substantial payload of ligands such as proteins, antibodies, and peptides. This capability facilitates the vectorisation of these materials to specific regions of interest, based on molecular recognition, thereby offering an ideal scenario for diagnosing a wide array of conditions across various diseases. We have demonstrated that this approach succeeds in imaging complex biological situations such as atherosclerosis, thrombosis, inflammation and cancer (Figure 1B) in a manner related to the disease progression [3]. Another potential application of radiolabelled materials is the tracking of single particles by positron emission particle tracking (PEPT). PEPT enables rapid and precise localisation of a single radiolabelled particle as it moves within a piece of equipment. So far, PEPT has been limited to industrial sectors due to the lack of suitable radiolabelled single particle tracers for biomedical applications. However, our recent demonstration of PEPT in biomedicine marks a significant advancement (Figure 1C) [4]. Implementing PEPT for biomedical applications might provide a novel and powerful diagnostic tool for real-time, whole-body assessment of blood flow dynamics in a quantitative manner.

Altogether, these findings underscore the transformative potential of nanomaterials in biomedical imaging. By uniting the molecular sensitivity of PET, the anatomical precision of MRI, and the emerging ability of PEPT to dynamically track single particles in real time, this field is moving toward a new paradigm in diagnostic imaging. Radiolabelled nanomaterials not only enable detailed evaluations of pharmacokinetics and biodistribution but also provide versatile platforms for molecular targeting through conjugation with

biological ligands allowing them to interrogate complex disease processes. Looking ahead, the integration of PEPT into biomedical research promises to unlock entirely new opportunities for real-time, quantitative assessment of blood flow and particle dynamics at the whole-body scale, expanding the diagnostic landscape of nanomedicine. In this way, nanomaterials represent not only a bridge between imaging modalities but also a foundation for next-generation approaches in precision medicine.

References

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Figures

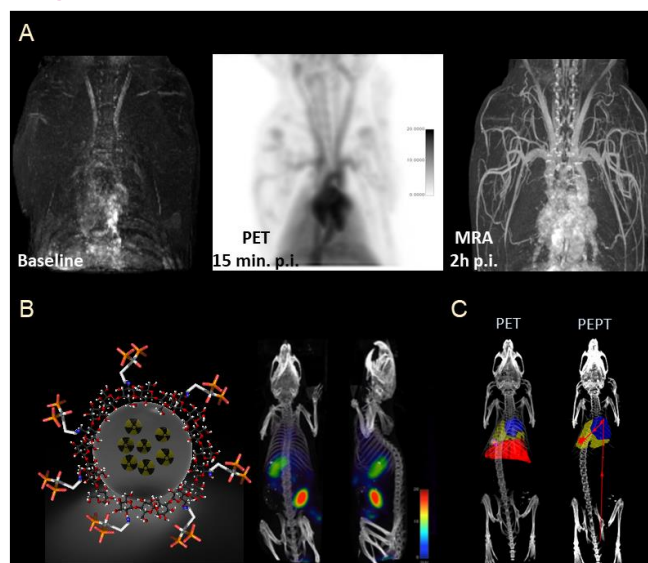


Figure 1. A. Magnetic resonance angiography (MRA) and positron emission tomography (PET) with ⁶⁸Ga core-doped iron oxide nanoparticle. B. targeting cancer with radiolabelled nanoparticles. C. In vivo PET imaging and positron emission particle tracking (PEPT) of a single radiolabeled sub-micron size silica particle.