When nanomaterials meet biology: Understanding what contributes to success and failure of materials in nanomedicine

Kristofer J Thurecht

Centre for Advanced Imaging and Australian Institute for Bioengineering and Nanotechnology; ARC Centre of Excellence in Convergent BioNano Science and Technology and ARC Training Centre for Innovation in Biomedical Imaging Technology
The University of Queensland
Brisbane, QLD, Australia
k.thurecht@uq.edu.au

Nanomaterials offer unique opportunities to modulate both temporal and spatial delivery of therapeutics owing to the ability to precisely control chemical and physical properties through rational design. However, it is important to understand fully how these properties vary under complex biological conditions, and how nanomaterials behave when exposed to biological cues that might be initiated through both endogenous and exogenous processes. Such complex behaviours requires the development of new approaches for probing biological systems, such that real-time assessment of both function and response can be achieved. Central to this idea is the field of theranostics, where molecular imaging is used to better understand how materials respond to changes in the environment during therapeutic delivery, or to monitor biological changes as a result of therapeutic delivery. Such materials require significant advancements in chemistry, materials science and engineering to ensure that the nanomedicine is both complementary with the biological milieu, but also able to withstand the harsh and often rapid environmental changes encountered upon injection into animals and in subsequent trafficking throughout the body.

In general, the ability to rationally optimise materials for *in vivo* drug delivery is hindered by the inability to directly assess the behaviour of the materials *in vivo*. And while biodistribution of nanomaterials and nanomedicines certainly provides initial evidence for successful delivery, it does not indicate whether a therapeutic has been successfully translocated into diseased tissue or diseased cells. Our work has focussed on developing self-reporting nanomedicines in which the nanomedicine is monitored in real-time using molecular imaging to inform on both delivery of the therapeutic, as well as efficacy of the treatment or cellular localisation of therapy. I will highlight how these studies offer unique insight into why some polymeric and biologic materials are effective, and others are not, as well as discuss the validation of personalised nanomedicines in canine trials with translation to clinical studies.