Photothermal nanomedicine: from cancer therapy to on-demand drug delivery

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Plasmonic nanoparticles (PNPs) exhibit unique optical properties that go beyond their fascinating colours. Their optical response is dominated by the localized surface plasmon resonance (LSPR), which represents the physical basis for a broad range of emerging applications addressing current and future challenges in nanomedicine. In particular, the LSPR phenomenon enables PNPs to efficiently convert resonant light into heat, making them excellent candidates as optical transducers for photothermal therapy (PTT). PTT has attracted growing attention as an alternative or complementary strategy to conventional anticancer treatments, as it enables the selective, on-demand ablation of cancer cells. Among PNPs, gold nanoparticles (AuNPs) are excellent photothermal transducers, enabling applications in PTT-based precision medicine. In this presentation, I will provide an overview of several applications in PTT-driven nanomedicine. Specifically, radiolabelled AuNPs injected into a microfluidic platform that mimics the renal filtering unit, the nephron, are used as novel theranostic agents that combine imaging and therapy. 3D-bioprinted constructs composed of U87-MG glioblastoma cells are investigated to assess the capabilities of PTT-based precision medicine in complex tumour environments. Microneedle arrays (MNs), a class of minimally invasive devices capable of crossing the skin barrier, are functionalized with gold nanorods (AuNRs) and used as multifunctional photonic microtools that combine plasmonic photothermal activation with polymer-dependent structural responses, demonstrating the capability of PTT to treat melanoma cells in 3D architectures. To broaden the application of PTT, cardiac fibrosis is treated by selectively photothermally ablating AuNR-loaded human cardiac fibroblasts, highlighting its applicability beyond oncology and toward cardiovascular disease. Moreover, a novel plasmonic hybrid delivery system composed of AuNRs assembled on the surface of lipid nanoparticles is used for spatiotemporally controlled plasmid DNA delivery, opening a new avenue in the field of on-demand gene therapy. Furthermore, novel PTT drug-release systems will be presented by realizing a novel generation of adhesive patches suitably functionalized with a random array of AuNRs for on-demand drug release.