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Energy-cascaded Upconversion Nanoparticles for 800 nm Activated Photodynamic Therapy

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Photodynamic therapy (PDT) is emerging as a novel clinical approach that uses light (including laser sources) and photoactivatable compounds (photosensitizers) for the treatment of various tumors and other non-malignant conditions. PDT has potential advantages over surgery and other therapies, being minimally invasive, with accurate targeting and few side effects. However, most clinical PDT agents are activated at wavelengths of 630-690 nm, at which the tissue penetration and effective depth of treatment are limited. Hence, one focus of current PDT research is to develop compounds sensitive to light at near-infrared (NIR) wavelengths. Upconversion nanoparticles (UCNPs) have been extensively explored for NIR-activated PDT due to their large anti-Stokes shifts, excellent bio-compatibility and photochemical stability. In order to overcome the heat effect from 980 nm excitation lasers in conventional UCNP-based PDT, we developed an energy-cascaded upconversion nanoplatform excited with 800 nm continuous lasers for PDT. $NaYF_4$:Yb,Er,Nd@$NaYF_4$:Nd core-shell nanoparticles were coupled with carboxylic acid-functionalized IR780 and rose bengal via direct electrostatic interactions and exhibited a large production of cytotoxic singlet oxygen under 800 nm laser excitation. Due to a close contact between each component, high energy transfer efficiencies of the energy-cascaded pathway (dye → upconversion nanoparticles→rose bengal) were achieved. With antenna effects contributed by near-infrared dyes attached to the nanoparticle surface, the photon harvesting ability of the UCNPs were dramatically improved (~ 30-fold) with low excitation power density being required for singlet oxygen production. Our nanoplatform has potential to achieve 800 nm laser-activated photodynamic therapy for treatment of challenging deep tumors.

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