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Editorial

Biomedical Nanotechnology for Optical Molecular Imaging, Diagnostics, and Therapeutics

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Molecular imaging is a rapidly emerging biomedical discipline that allows for cellular observation to anatomical investigation in living subjects. It may be defined as visual depiction, characterization, and quantification of biological and/or pathological status at scalable levels. Biomedical nanotechnologies have been applied in many fields, such as optical imaging, ultrasonography, X-ray computed tomography (CT), magnetic resonance imaging (MRI), and positron emission tomography (PET), to name a few. Nanoplatform-based optical molecular imaging, a fast-growing field that bridges material chemistry, instrumentation engineering, and molecular biology, holds promising potential for early disease detection, cancer therapy, and treatment efficacy evaluation. Targeting ligands/antibodies, imaging molecules, therapeutic drugs, and many other nanoparticles can all be incorporated into the nanoplatform to allow for targeted molecular imaging and therapeutic purposes.

Magnetic resonance imaging (MRI) is the one of most widespread approaches in clinic. However, MRI employs nonportable and costly imaging equipment and provides weak functional contrast. Compared with X-ray CT and PET, optical imaging is noninvasive and eliminates accumulated harmful radiation to the body. Generally, optical imaging modalities may be characterized with utilizing of visible, ultraviolet, and infrared light techniques in imaging. Optical molecular imaging is highly desirable because it is a function approach to observe biological processes. On the other hand, molecular imaging can supply diagnostic information to guide therapeutic procedures.

Optical imaging modalities may be categorized into diffusive and ballistic imaging systems. Diffuse optical tomography (DOT) utilizes near-infrared light to detect absorption as well as scattering properties of biological tissues. The technique has various applications to neural activities, wound monitoring, and cancer detection. Core-shell upconversion nanoparticles have been reported to improve the spatial resolution of DOT. Also gadolinium (Gd) and indocyanine green (ICG) were found to greatly enhance the image contrast.

Current typical ballistic imaging methods, such as fluorescence imaging, confocal microscopy (CM), and optical coherence tomography (OCT), have critically impacted bio-imaging. Fluorescence microscopy (FM) was greatly advanced by the discovery of fluorescent proteins such as green fluorescent protein (GFP), photoconvertible/photoswitchable protein, and their variants, from various marine invertebrates. This technology enables systematic localization, structural imaging, and function imaging of protein in living cells and tissues. CM and OCT are optical techniques providing images with micron and sub-micron spatial resolution, respectively. Conventionally employed fluorescent nanoparticles, such as fluorescent dyes and proteins, possibly have harmful side effects, such as photo-bleaching and toxicity. Recently, gold nanoparticles and their conjugates have been extensively studied as contrast agents in optical imaging since they are not susceptible to photo-bleaching and can also target biochemical cells markers.

Unfortunately, ballistic optical imaging techniques cannot penetrate biological tissue deeper than the optical transport mean free path (~1 mm in the skin) due to strong optical scattering. Moreover, no single imaging modality can unveil overall anatomic, functional, and molecular information in a biological system. The combination of different imaging modalities offers more thorough pathological information. Photoacoustic imaging (PAI), one of the most successful hybrid imaging modalities, converts pulsed laser energy into ultrasonic waves to form images. Therefore, by ultrasonically breaking through the optical scattering limit, PAI can achieve both high ultrasonic resolution and rich optical contrast. Recent work in nanoparticles for PAI is focused on optimizing absorption properties, as well as designing unique functions and features. Specifically, these exogenous contrast agents include organic dyes, reporter genes, fluorescent proteins, or metallic nanoparticles such as gold nanorods, cages, and shells. Thermoacoustic tomography, sharing the same mechanism with PAI, utilizes microwave or radio-frequency to obtain deeper penetration depth in tissue.

Interdisciplinary research that couples molecular imaging science to nanotechnology could provide valuable information that would impact preclinical and, eventually, clinical studies. Nanoplatform-based optical imaging creates the potentials to achieve several important goals: (1) to advance noninvasive and non-ionizing imaging techniques that reveal specific biological and pathological information; (2) to synthesize and modify

novel nanoparticles for diagnostics, drug delivery, and disease therapy; (3) to image lesion and record therapeutic response at a molecular and cellular level, and optimize drug therapy efficacy; and (4) to achieve the above goals in a combined platform to be capable for early stage diagnostic, therapeutic monitoring, and treatment efficacy evaluation in an effective, robust, and quantitative manner.

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