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Photothermal Therapy and Nanomaterials

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Recently, several light absorbing nanomaterials have been developed for photothermal therapy of cancer, which involves localized heating and killing of cancer cells via light [1-10]. Importantly, the use of light absorbing nanomaterials for phototherapy allows a precise control over the target site, time and rate of payload release, providing effective cancer treatment. Compared to other nanomaterials used for formulation of nanoparticles as therapeutic carriers, light absorbing nanomaterials have more advantages. For instance, these light absorbing nanoparticles can be actively delivered to the tumor site and further exposed to light to produce heat locally for hyperthermia therapy, and to release payloads including chemotherapeutic reagents to significantly kill cancer cells at that site. This will enhance the therapeutic effectiveness and reduce the side effects of therapeutic agents, compared to either systemic delivery or passive targeting and passive release of drugs at the tumor site. The commonly used light absorbing materials include gold-based (e.g. gold nanoparticles, gold nanoshells, gold nanorods and gold nanocages), silica-based (e.g. silica-cored gold nanoshells), other inorganic (e.g. carbon nanotubes, titanium nanoparticles and titanium nanotubes), and polymeric materials (e.g. liposome structure-based nanoparticles, porphysomes and polymeric nanoparticles).

Photosensitizers, which are nontoxic to cells in the absence of light and are activated by light to produce cytotoxic molecules that kill cancer cells, can also be loaded in light absorbing nanomaterials for enhancing photodynamic therapy (PDT). In addition to destroying cancer cells, photosensitizers are also able to produce intense fluorescence signals at the tumor site for photodynamic imaging (PDI). Both PDT and PDI can be simultaneously used for better effectiveness of cancer therapy. However, most of the photosensitizers are hydrophobic or poorly soluble in water and non-specific to cancer cells, limiting their therapeutic applications. To overcome these limitations, nanomaterials/nanoparticles as targeted carriers for photosensitizers can be designed and employed to improve specificity, so that they would have many applications in diagnosis and treatment of various diseases, including cancers. The potential applications of these materials in medicine are imaging, drug delivery, photothermal therapy and combined therapies. Thus, theranostic light absorbing nanomaterials containing fluorescent, therapeutic and photothermal agents could provide the best effective modality in clinical oncology due to their multifunctional properties.

Indeed, advances in nanomedicine have recently allowed us to fabricate multifunctional nanoparticles consisting of targeting, therapeutic and diagnostic functions in a single setting. When nano-imaging technology is coupled with localized drug delivery platforms, the impact in therapies for cancers and other diseases is significantly high. It is even better if these nanomaterials can be designed, so that their structure changes can be controlled by a specific stimulus, including changes in either temperature or pH, irradiation with light, or the application of an alternative magnetic field, in order to release the therapeutic payload. Furthermore, advanced knowledge in the photochemistry of imaging agents and/or drugs, and modifications of these reagents using light will facilitate the development of new generation theranostic nanoparticles for photothermal therapy, for both cutaneous and deep tissue tumors.

Although the use of light in combination with light absorbing materials is a promising means for targeted phototherapy, this method still has a number of limitations. First of all, most materials are developed to respond to UV and visible light, thus, they can only be applied to topical applications where the light penetration is not a limitation. On the other hand, expensive high-energy lasers might be required when nanomaterials are applied to deep tissues. The potential for damaging adjacent tissues and therapeutic payloads by high-energy light sources might diminish the potential use and functionality of the system, especially when proteins, growth factors and hormones are involved. In addition, several property aspects of light absorbing nanomaterials, including toxicity, thermal stability and involved photochemical mechanisms, remain to be thoroughly investigated. Furthermore, design and synthesis of novel light-absorbing synthetic materials that could be degraded upon irradiation would eliminate the need for inorganic materials, and could be used for many biomedical applications. Moreover, more standardized methods and reports are needed for characterizing of the photothermal therapy, and for helping to understand more of this process. For instance, the effects of irradiation and the photochemical parameters (e.g. particle concentration, wavelengths, exposure time, laser power density/laser power per area, energies per pulse, and so on) on changes of the systems (including swelling, de-crosslinking, degradation, cell viability, cellular uptake, in vivo toxicity and targeting efficiency of the carriers) should be further investigated to obtain meaningful conclusions, so that selecting an appropriate system for potential medical applications would be possible. Finally, the potential extension of the light absorbing nanomaterials to other medical applications, such as infection, gene therapy and stem cells, as well as the potential use of cells like macrophages and stem cells as a carrier to specifically deliver these nanomaterials at a desired location, would bring in a great promise for this research field.

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