Using gold nanoparticles for cancer imaging and drug delivery

Rui Hu

Fine-engineered, tiny noble-metal particles can be used for targeted color imaging of cancer cells and potentially for therapy.

Having fought cancer for decades, medical doctors and researchers still face brick walls blocking further progress, such as when attempting to find and precisely track cancer cells, especially at an early stage. Nanotechnology offers promising options. For example, nanorobots proposed years ago would navigate the blood stream and recognize, target, and clear cancer and other cells that cause diseases. But many obstacles remain, and it will take time to achieve the ultimate goal. Engineering nanoparticles or nanocrystals is a good start.

Thanks to the fast development of nanotechnology, nanoparticles made from different materials have been introduced extensively into biomedical research. Semiconductor nanocrystals, also known as quantum dots (QDs), have attracted attention since the late 1990s.¹,² They have unique optical properties, the most important of which is size-dependent, tunable photoluminescence. QDs emit different colors depending on their size when illuminated with an excitation light source, giving them broad applications in bio-imaging. However, there are still some drawbacks. One of the biggest concerns is potential toxicity, because most QDs contain heavy metals. As an alternative, we proposed using nanoparticles made of noble metals (specifically gold and silver), which resist corrosion or oxidation.

During the past two decades, fabrication methods of anisotropic gold nanoparticles have been evolving, especially for nanorods.³ Because of localized surface-plasmon resonances, gold nanorods exhibit strong scattering in two wavelength bands, one of which is tunable in the visible and near-IR ranges by adjusting the aspect ratio (length to width). As a result, in a dark-field microscope, where only scattered light is collected, gold nanoparticles appear as bright, colorful dots. After surface modification, we used them as contrast agents for cell labeling.

To get more colors for multichannel imaging, we synthesized gold nanorods and silver nanospheres as contrast agents, since they appear as red and blue dots, respectively, in a dark-field microscope.⁴ More recently, we found an even better way. By coating gold nanorods with a thin layer of silver during synthesis, we were able to get a set of nanoparticles with different colors covering the visible and near-IR ranges.⁵

We covered the synthesized nanoparticles with a thin layer of positively charged surfactant molecules to prevent aggregation.

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To improve biocompatibility, we coated the nanoparticles with a negatively charged biocompatible polyelectrolyte through electrostatic physisorption. The nanoparticles were then covered again with a positively charged biocompatible polyelectrolyte to enable them to absorb a transferrin, a biomolecule on the surface whose complementary receptor is overexpressed on cancer-cell surfaces.

To demonstrate this, we incubated different sets of nanoparticles modified with transferrin with pancreatic cancer cells for two hours, during which the nanoparticles were absorbed onto the cell surfaces by the specific binding effect between transferrin and its complementary cell-surface receptor. Under a dark-field microscope, nanoparticles of different colors (green, orange, or red) can be clearly seen spreading out on the cancer cells (see Figure 1). We have thus successfully demonstrated that biofunctionalized metallic nanoparticles can be used for specific cell tracking and imaging. Note that since the light scattering by the nanoparticles is so strong, it can be detected even at the single-particle level, so that these nanoparticles can serve as a potential platform for multichannel, ultrasensitive bio-imaging.

Engineering nanorobots to fight diseases is an ultimate goal for biomedical research, and starting with nanoparticles seems promising. Note that while the particles perform tracking and imaging, our recent work has also demonstrated that they can be used as nanosized carriers to deliver drugs efficiently into cells for disease treatments such as the pandemic H1N1 influenza. Based on the in vitro results, our next step will be to use metallic nanoparticles for in vivo animal experiments, thus pushing forward their biomedical applications.

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References