Photoacoustic navigation for photo-thermal therapy

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Background, Motivation and Objective

Photo-thermal therapy (PTT) has been widely investigated for cancer treatment. Gold nanoparticles (AuNPs), due to their extremely strong optical absorption and thermal conversion as a result of surface plasmon resonance, have shown great performance as mediators in PTT. Besides, AuNPs can also be guided in PTT for their own excellent photoacoustic conversion using photoacoustic imaging (PAI).

Statement of Contribution/Methods

We have explored the feasibility and performance of PAI-guided PTT of cancer mediated by gold nanostars (AuNSs). By coating silicon around AuNSs, their star shape can be maintained well during PTT and PAI. The melt-re-solidification effect can be significantly reduced. As a result, the optical absorption spectrum of the AuNSs is more stable over repeated treatment using PTT. In this work, the silica coating with various thicknesses was first tested on phantoms and in vitro, aiming at finding the optimal design leading to the best photo-stability. Then, by using a PAI and ultrasound (US) dual-modality imaging system, we examined the performance of the silica coated AuNSs in vivo by conducting the PAI-guided PTT on a mouse model of cancer.

Results/Discussion

The AuNSs synthesized using the amount of 100 μL of TEOS corresponding to a coating thickness of around 30 nm achieved the best photo-stability. With this coating, no obvious color change was noticed when the AuNSs were illuminated continuously over a total duration of 60 seconds by 40 mJ/cm^2 fluence of laser light at 850 nm wavelength, as observed in the experiments on phantoms and in vitro. As observed under TEM, with the silica coating, there was little change in the AuNS morphology, and the star shape was maintained well after the treatment. In comparison, the AuNSs without silica coating were mostly melted to spheres. In the experiments in vivo, the targeted delivery of the AuNSs to the tumor areas were clearly observed, demonstrating the excellent contrast enhancement to both PAI and PTT brought by the AuNSs. During repeated PTT of the target tumors, the silica-coated AuNSs demonstrated much improved photo-stability compared to those without silica coating. With the silica coating, the speed in photoacoustic signal decreasing was reduced by 3 folds when the tumors were illuminated by 850-nm laser with fluence of 40 mJ/cm^2.

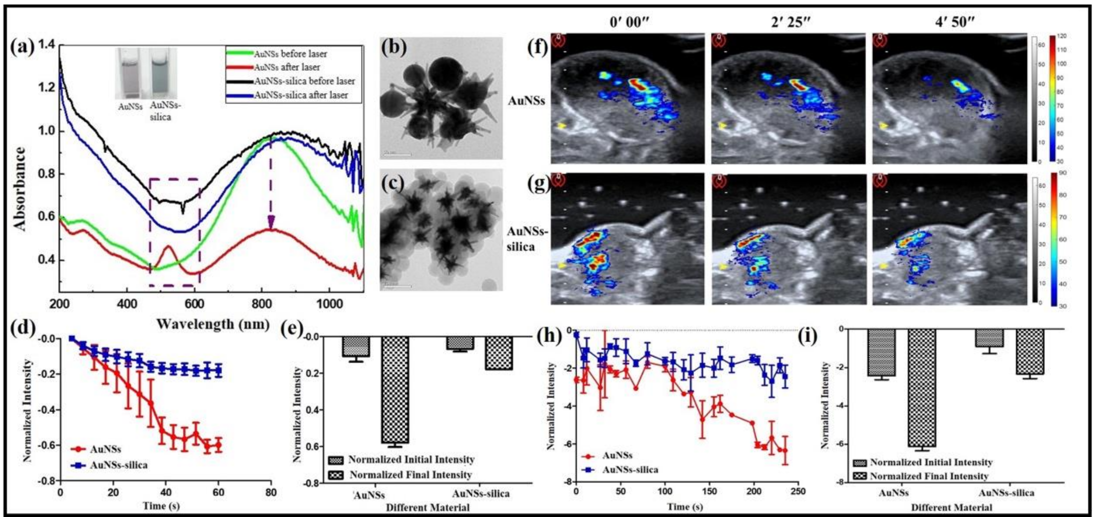

Fig. 1. (a) Comparison of UV-vis-NIR spectra of AuNSs, with and without silica coating, before and after illumination by pulsed laser light. TEM images of (b) AuNSs after laser illumination, showing the morphological change due to the melting, and (c) silica-coated AuNSs, demonstrating good preservation of the star shape. (d) The photoacoustic signal intensity change when the AuNSs with silica coating (AuNSs-silica) and the AuNSs without silica coating (AuNSs) were illuminated by the laser light. (e) Normalized photoacoustic intensity change from the beginning to the end of the laser illumination (60 seconds). (f) PAI and US combined images of a tumor containing specifically delivered AuNSs without silica coating. The combined images were acquired at different time points during the treatment, showing quickly decreased photoacoustic signals from the AuNSs. (g) PAI and US combined images of a tumor containing specifically delivered AuNSs with silica coating. The decreasing speed in photoacoustic signal intensity was reduced by the silica coating. (h) The photoacoustic signal intensities in the tumors as a function of time, where the result using AuNSs with silica coating (AuNSs-silica) was compared to the result using AuNSs without silica coating (AuNSs). (i) Normalized photoacoustic intensity change in the tumor from the beginning to the end of the laser illumination (240 seconds).