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Application of organic IR788-loaded sIPN dyes for photoacoustic imaging

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1. Introduction

Photoacoustic imaging (PAI) has been proposed as an alternative technique to overcome the limitations of conventional optical and ultrasonic imaging systems such as MRI, PET, and US due to high optical absorption and high ultrasound resolution [1]. PAI relies on the generation of photoacoustic waves by illuminating short laser pulses on tissue. The acoustic waves can be detected by using a high sensitivity ultrasound transducer and then used to reconstruct 2-D PA images. PAI imaging demonstrates various optical absorption contrasts in tissue or and is capable of providing the accurate location and characteristic of solid tumor as well as geometrical information of the tumor tissue with high contrast and high spatial resolution. On the other hand, most diseases could hardly generate the natural acoustic signals due to their optical transparency in the near infrared window, leading to difficult diagnosis by applying PAI. Thus, the development of exogenous contrast agents is essential to allow for therapeutic feedback and instantaneous responses to treatment.

Recently, nanotechnology has been extensively explored and engendered a number of nanomaterials such as gold nanostructures, carbon nanomaterials, and copper sulfide nanoparticles as promising photo-absorbing contrast agents for cancerous diagnosis due to a strong near-infrared absorption efficiency [2]. However, the major limitation of these agents for tumor visualization is still associated with long-term toxicity due to remaining inside the body for long periods of time after systemic administration. Thus, the aim of the current study was to investigate the fabrication of a biocompatible IR788-loaded sIPNs as a novel photoabsorbing agent for PA imaging. Compared with the aforementioned inorganic agents, the modified IR788 sIPN exhibited low toxicity and cost effectiveness, making it suitable for PA imaging.

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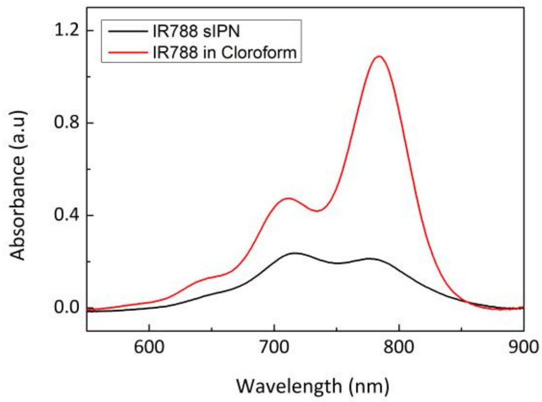

Fig. 1. UV-vis NIR absorbance spectrum of IR788 sIPN.

2. Material and Methods

The potential application of IR788 sIPN dyes for enhancing photoacoustic image contrast was examined by using a PAI imaging system on phantoms at various wavelengths. Four concentrations of IR788 dyes (i.e., 0 as control, 6%, 8%, and 10% w/w) were used for PAI mapping. As an imaging source, a tunable (λ=680~2500 nm) OPO laser (Surelite OPO Plus, San Jose, CA) was pumped by using a Q-switched Nd:YAG (Surelite II, Continuum, San Jose, CA) and generated a laser pulse with a pulse duration of 5 ns at 10 Hz. To identify the spectroscopic effects of wavelength on 2-D image reconstruction ranging from 780 to 820 nm, an increasing step of 20 nm were employed on the samples. Upon laser irradiation, each specimen induced photoacoustic signals, which was detected by using a spherically focused single-element 5 MHz ultrasound transducer (V308, Panametrics, Waltham, MA) with a focal length of 2.54 cm. The laser beam was aligned with the focal region of the imaging ultrasound transducer in degassed water, and for 2-D imaging, each sample in the tissue holder was moved along x- and y-direction on a 2-D translation stage. The received photoacoustic signals were filtered and amplified by a low-noise amplifier (5072 PR, Olympus, Waltham, MA), which, in turn, were converted into digital signals and recorded by a digital oscilloscope (TDS 5040, Tektronix, Beaverton, OR). Finally, the recorded data was used to reconstruct 2-D images. The axial and transverse resolutions of the current PAI system were 144 and 590 µm, respectively. The image contrast, which was defined as the difference between the signal intensity of the targeted area and its background, was estimated from the reconstructed images as described in a previous study [3].

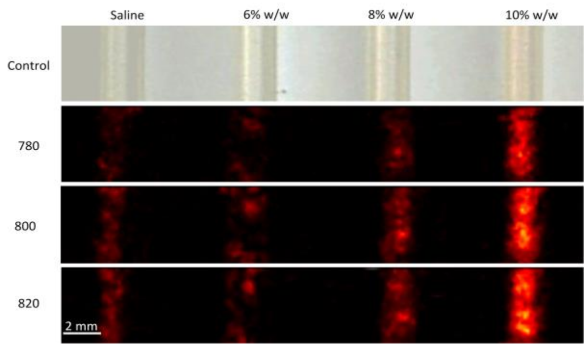

Fig. 2. PAI mapping of phantoms filled with IR788 loaded sIPNs: photograph of phantom, and correspoding PA image acquired at 780, 800 and 820 nm wavelengths, respectively.

3. Results

Fig. 1 shows the Uv-vis spectra of synthesized IR 788 sIPNs dyes. The absorption spectra of the IR788 were measured between 550 and 900 nm by using a spectrometer (XS2, BioTek, Winooski, VT, USA). The spectra measurement demonstrated that the peak absorbance band of IR788 sIPNs ranged from 720 to 820 nm. According to the spectral data, 800 nm was considered the maximum excitation wavelength for PAI.

Photoacoustic imaging effect of IR788 sIPN dyes were further illustrated at the phantom level. The PA of phantom was implemented on artificial phantoms (i.e., tube with 2 mm in diameter). Fig. 2 presents images of the phantoms filled with various concentrations of IR788 sIPN and the corresponding PA images acquired at different wavelengths ranging from 780 to 820 nm with a 20-nm increment. All the samples were clearly observable at a high concentration of 10% w/w IR780 sIPN. On the other hand, the samples with lower concentrations exhibited relatively indistinctive image possibly due to lower light absorption.

Fig. 3 depicts the mean PA amplitudes as a function of IR788 sIPN concentration at different wavelengths to determine the optimal PAI wavelength for identifying the targeted tissue. Overall, the measured PA amplitudes were linearly increased with the IR788 sIPN concentrations. Quantitative measurements in Fig. 3(a) also illustrates that the wavelength of 820 nm achieved the maximum PA amplitude in comparison with the other wavelengths. Fig. 3(b) quantitatively compares the acquired PA amplitudes at different positions from the image at 820 nm in Fig. 2. Compared to background, the acquired PA image contrast was quantified to be 6.5±0.8, 3.3±0.8, 2.2±0.7, and 1.6±0.3 for 10, 8, 6, and 0 (saline) %w/w, respectively. Apparently, the 10% w/w sample exhibited the highest image contrast, and the contrast gradually decreased with the decreasing concentrations.

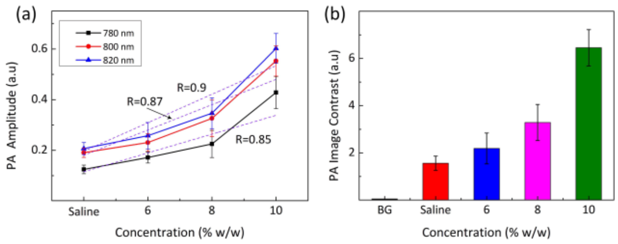

Fig. 3. Spectroscopic evaluations on (a) PA signal amplitude and (b) comparison of PA image contrast acquired at 820 nm from phantom samples.

4. Conclusion

The current study demonstrated that the proposed IR788 loaded sIPNs could be used as a novel photo-absorbing agents for PAI. As organic agents, the IR788 dyes were nontoxic and biodegradable for imaging application. Due to selective light absorption, the IR788 loaded sIPNs could be a safe contrast agent for imaging-guided cancer treatment during clinical applications.

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References

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