1P5-14

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 151-152
3-5 December, 2014

Detection of Solid Tumor under Laser Treatment with High-Resolution Photoacoustic Imaging

Van Phuc Nguyen[1‡], Kanglyeol Ha[2], Junghwan Oh[1], and Hyun Wook Kang[1]
([1]Biomedical Eng. Dept., Pukyong Nat'l Univ., [2]Dept. of Physics, Pukyong Nat'l Univ.)

1. Introduction

In recent decades, the advance technique for guiding and monitoring laser treatment has been investigated such as magnetic resonance imaging (MRI) and ultrasound imaging. MRI has been demonstrated that it could be used in real-time to provide temperature maps.[1] However, MRI scanners are still expensive and bulky systems with lengthy scanning time and clinical accessibility. As an alternative, ultrasound imaging systems are relatively cost-effective, but they have the lack of accuracy and specificity as well as low image contrast particularly for noninvasive localization and treatment evaluation.[2]

Recently, photoacoustic imaging (PAI) has been proposed as an alternative technique to guide or monitor laser therapeutic and overcome the limitation of conventional optical and ultrasonic imaging system. PAI is a non-ionizing, non-invasive, cost-effective, and hybrid imaging technique that can provide high optical absorption with high ultrasound resolution.[3] Therefore, PAI holds a promise for diagnostic imaging and guided therapy of bladder cancer. PAI relies on the generation of photoacoustic waves by illuminating short laser pulses into tissue. The acoustic waves can be detected by a high sensitivity ultrasound transducer and then used to reconstruct 2-D PA images. PAI imaging demonstrates different optical absorption contrast in bladder tumor and is capable of providing accurate location and characteristic of solid tumor as well as shape information of tumor tissue with strong contrast and high spatial resolution. Thus, the aim of the current study was to investigate the potential treatment of solid tumor by integrating photoacoustic imaging (PAI) with high power laser system. During this study, photoacoustic imaging was utilized with various wavelengths to precisely locate the position of bladder tumor. The combined system can be utilized for characterizing structural variations in solid tumor tissue as well as monitoring thermal ablation process generated by laser.

Email: wkang@pknu.ac.kr

2. Material and Methods

Fig. 1 presents a schematic diagram of the integrated PAI and laser system for imaging of tumor in a bladder before and after thermal treatments. An 80-W 532-nm laser system was utilized for thermal treatment on fresh canine bladder tumors. This laser system generated 30 to 40 W energy in order to coagulate the targeted bladder tumors. A standard 400 to 600 μm fiber was used to deliver generated energy from laser system to the tissue. The tip of fiber was placed at the distance of 3 to 4 mm from the papillary tissue. The laser system was activated until the tissue demonstrate a whitish discoloration. During the experiment, peak temperature rise of tissue under treatment was measure by a thermocouple (GT307, Gilwoo Company, Korea).

The targeted tissues after ablation were imaged by PAI imaging system at various wavelengths. As an imaging source, a tunable (λ=680~2500 nm) OPO laser (Surelite OPO Plus, San Jose, CA) was pumped by a Q-switched Nd:YAG (Surelite II, Continuum, San Jose, CA) laser with a pulse duration of 5 ns at 10 Hz. To identify the spectroscopic effects of wavelength on 2-D image reconstruction ranging from 700 to 900 nm were employed on the thermally treated tissues. The laser light from OPO was coupled into a fiber optic and focused onto the targeted tissue at the distance of 4 mm as illustrated in Fig. 1. Upon laser irradiation, each specimen induced photoacoustic signals, which was detected by 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 of the laser-treated bladder tumors. The axial and transverse resolutions of the current PAI

system were 144 and 590 μm, respectively.

In order to improve PA sensitivity, indocyanine green (ICG) was chosen as a contrast agent and was injected into the bladder tissue.

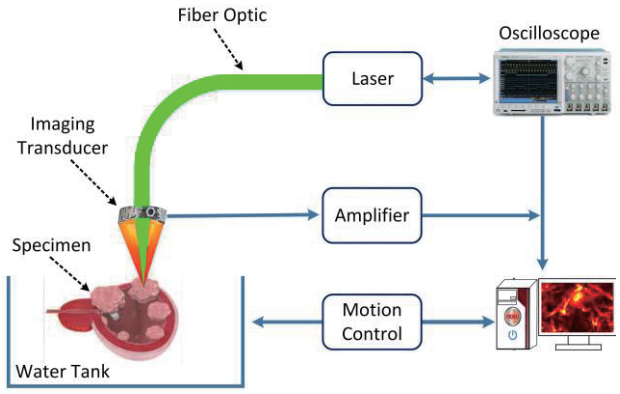
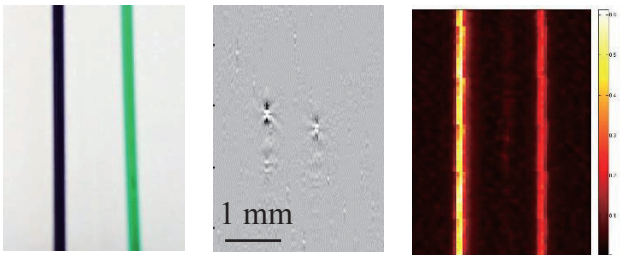


Fig. 1. Schematic diagram of integrated system of PAI and laser.

3. Results

In order to quantify the performance of PAI system, an experiment was implemented on artificial phantoms (i.e. tube with 2 mm in diameter) was acquired. Fig. 2(a) presents images of phantom filled with Blue dye and ICG taken by a PAI system (λ = 750 nm). Fig. 2(b) shows a cross-sectional B-scan mode image of the phantom. The image represented a spatial resolution of 300 and 200 μm in lateral and axial axes, respectively. The acquired PA image (Fig. 2(c)) demonstrated higher contrast in the amplitude of PA signals compared to the background area. After laser treatment, the coagulated tissue demonstrated higher contract than the peripheral untreated region, by yielding higher amplitude of PA signals.



(a) (b) (c)

Fig. 2. PAI mapping of phantom filled with indocianine green (ICG): (a) photograph of phantom, (b) Cross-sectional image of phantom, and (c) PA image of phantom acquired at 700 nm wavelength

4. Conclusion

The results in this study have suggested that, a PAI-guided system could be used to identify the precise position of the targeted tissue with clear and high contrast. The PAI guidance can be a feasible tool to provide the real-time monitoring and evaluate the treatment process during clinical applications.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (NRF-2012R1A1A1012965).

References

1. A. Tekes, I. Kamel, K. Imam, G. Szarf, M. Schoenberg, K. Nasir, R. Thompson and D. Bluemke, Amer. J. Roentgenology, 184(2005)121
2. Z. Yuan, Z. Wang, R. Pan, J. Liu, H. Cohen and Y. Pan, JBO 13(2008).
3. S. Mallidi, G.P. Luke and S. Emelianov, Trends in Biotechnology, 29(2011)213