나노초 레이져를 이용한 광-초음파 이미지 결상법
In vivo functional photoacoustic imaging

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ABSTRACT

Functional photoacoustic tomography is a new non-invasive imaging modality, and it is emerging as a very practical method for imaging biological tissue structures by means of laser-induced ultrasound. Structures with high optical absorption, such as blood vessels, can be imaged with the spatial resolution of ultrasound, which is not limited by the strong light scattering in biological tissues. By varying wavelengths of the laser light and acquiring photoacoustic images, optical absorption spectrum of each image pixel is found. Since the biochemical constituents of tissues determine the spectrum, useful functional information like oxygen saturation (SO_2) and total haemoglobin concentration (HbT) can be extracted. In this study, as a proof-of-principle experiment, hypoxic brain tumor vasculature and traumatic brain injury (TBI) of small animal brain are imaged with functional photoacoustic tomography. High resolution brain vasculature images of oxygen saturation and total hemoglobin concentration are provided to visualize hypoxic tumor vasculature, and hemorrhage on the cortex surface by the TBI.

Keywords: photoacoustic tomography, tumor hypoxia, neovacularization, spectroscopic imaging, blood oxygenation

1. INTRODUCTION

Functional photoacoustic tomography is a new non-invasive imaging modality, and it is emerging as a very practical method for imaging biological tissue structures by means of laser-induced ultrasound.[1] Structures with high optical absorption, such as blood vessels, can be imaged with the spatial resolution of ultrasound, which is not limited by the strong light scattering in biological tissues. By varying wavelengths of the laser light and acquiring photoacoustic images, optical absorption spectrum of each image pixel is found. Since the biochemical constituents of tissues determine the spectrum, useful functional information like oxygen saturation (SO_2) and total haemoglobin concentration (HbT) can be extracted. Oxygen saturation of vasculature on the brain cortex has been successfully measured functional photoacoustic tomography.[2]

In this study, hypoxic brain tumor vasculature and traumatic brain injury was imaged with functional photoacoustic tomography. High resolution brain vasculature images of oxygen saturation and total hemoglobin concentration are provided to visualize brain vasculature. Because of the location of the tumor inside brain, conventional optical imaging modalities were not able to detect in vivo vasculature information with the order of sub mm spatial resolution so far. Hypoxic brain tumor cells were inoculated, and the tumor positions and hypoxia are identified by low oxygen saturation (SO_2) and high total hemoglobin concentration (HbT) of vasculature. As a TBI case, The time courses of hemodynamic response following trauma initiation were imaged with multi-wavelength photoacoustic tomography

2. RESULTS

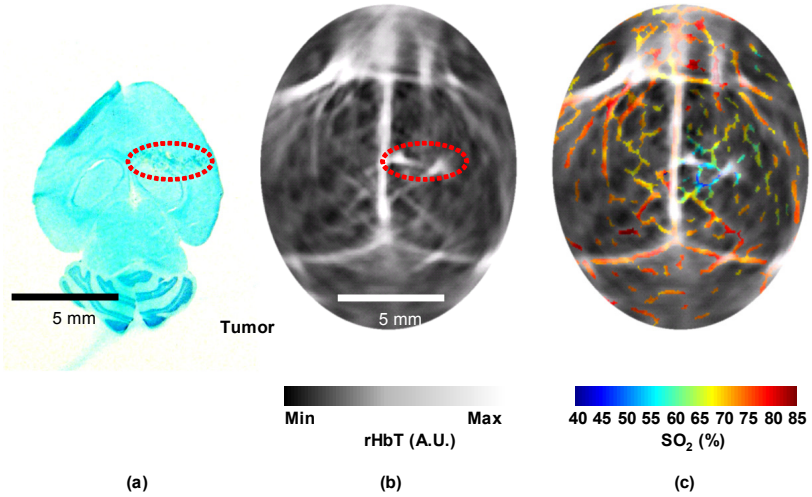

Figure 1. Non-invasive functional photoacoustic imaging of the total concentration of hemoglobin (HbT) and the hemoglobin oxygen saturation (SO_2) inside a nude mouse brain with U87 cell lines. (**a**), microslide cross section colored with Thionine staining. (b) and (c), Images of relative HbT and SO_2 inside a nude mouse brain.

Functional photoacoustic images of mouse brain with hypoxicU87 glioblastoma tumor is shown in Fig. 1 with corresponding histology. Thionine stained microslide imge in Fig.1(a) indicates tumor at the middle of right hemisphere of brain. Microslides from other depths verify that the solid tumor was developed inside brain only. At the same anatomical position of tumor in the HbT image in Fig. 1(b), strong total haemoglobin value is observed. SO_2 image Fig.1(c) also indicates low oxygen level at the same position. HbT value in tumor vasculature is 3 ~4 times higher than normal vasculature inside brain. The difference in SO2 between hypoxic tumor vasculature and normal blood vessel is over than 20% in Fig.1. The SO2 image shows larger area of hypoxia than HbT and microslide images.
health vessel is low HbT and high SO_2 while hypoxic tumor vasculature has high HbT and low SO_2 with large fluctuations in these values.

Reference

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