Towards in vivo Photoacoustic imaging of vulnerable plaques in carotid artery

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Background, Motivation and Objective

Rupture of a vulnerable carotid plaque is a major cause of stroke. Currently, the degree of carotid stenosis is widely used in clinics to assess the risk of stroke, which is routinely estimated by duplex ultrasound. According to the guidelines, a patient with a stenosis grade > 50% will be treated, which results in severe overtreatment. Therefore, a more effective risk assessment for the individual patient is a strong, unmet clinical need. PA/US imaging can provide comprehensive (both morphology and chemical composition) and patient-specific assessment of plaque vulnerability. Despite many ongoing efforts, in vivo PA imaging of carotid plaques remains a big challenge mainly due to the low PA SNR in the in vivo setting. In this study, in vivo PA/US imaging of carotid plaques was investigated in a pre- and perioperative clinical pilot study.

Statement of Contribution/Methods

In this paper, a fast PA/US imaging system (laser pulse rate: 1 kHz) with a fully integrated hand-held PA probe is used. The PA imaging system operates at the wavelengths of 808 and 940 nm, aimed at imaging intra-plaque hemorrhages, a major biomarker to identify vulnerable plaques. To increase the SNR for in vivo PA imaging, a new motion corrected PA averaging algorithm (based on a speckle tracking method) is used. The system and algorithms were validated ex vivo in phantoms and in a designed pre-clinical experiment. Next, we started the first clinical study on PA/US imaging performed on patients undergoing a carotid endarterectomy as a first step towards clinical application.

Results/Discussion

Significant improvement on PA SNR (up to 13dB) was achieved by applying the proposed method on the ex vivo PA images from the phantom and human carotid plaque samples. Then, we got the first in vivo intra-operative PA/US images on patients (Fig.1). Results revealed good signal levels in the intra-operative PA images: the PA signal from the plaque (from 9 o'clock to 4 o'clock direction, Fig. 1b) is clearly enhanced (+ 10 dB) after motion corrected averaging. The fast PA/US imaging system and the motion corrected averaging may accelerate the clinical translation of PA/US imaging of carotid plaques, although non-invasive imaging will require further improved SNR and clutter reduction.

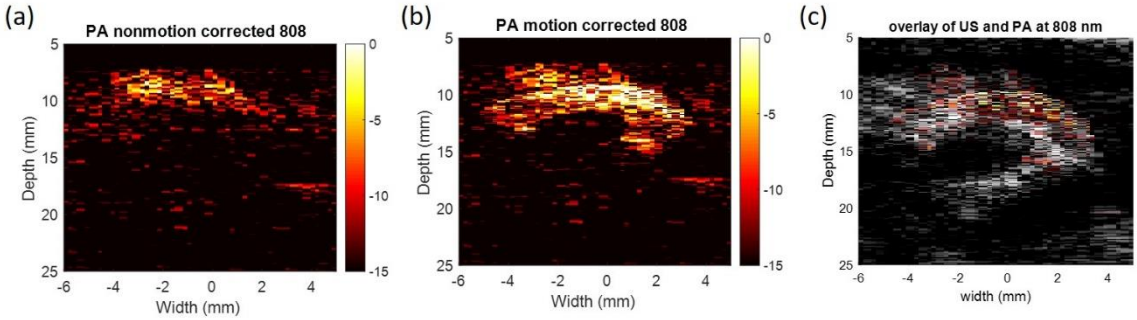

Fig.1. in vivo (intra-operative) PA/US images of the human carotid plaque . (a) non-motion corrected 190 X averaged PA image and (b) motion corrected 190 X averaged PA image and (c) overlay of US and PA image of the human carotid plaque