An *in silico* toolchain for dynamic 3D photoacoustic imaging of the carotid artery

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Background, Motivation and Objective

Atherosclerotic plaque rupture in the carotid artery is a main cause of ischemic strokes. The decision to remove the plaque by surgery is solely based on the grade of stenosis in the artery. This guideline leads to severe overtreatment of patients, as stenosis grade by itself is not a good indicator for plaque rupture. In previous research, it has been shown that photoacoustic (PA) imaging could improve diagnosis by characterizing plaque compositions, instead of plaque size only. Research on PA imaging, however, is impeded by the scarcity of high quality phantoms and the absence of a ground truth in experiments. An *in silico* method to simulate PA imaging can provide a research environment in which the exact tissue and noise properties are known and controllable and this method was therefore developed in this study.

Statement of Contribution/Methods

A toolchain, consisting of three steps, was made to simulate PA imaging in the carotid artery in 2D and 3D. First, tissue motion due to blood pressure was modelled over time in a finite element model. The carotid artery mesh was obtained using 2D ultrasound acquisitions for which a probe tracker was used to obtain a 3D reconstruction (**Fig 1a**). In the next step, the optical energy absorption and the initial pressure field in the tissue was determined using a Monte-Carlo method. In the last step the acoustic pressure field was simulated using the k-Wave software and image reconstruction is performed. Next to PA imaging, plane wave B-mode ultrasound imaging was also incorporated in the toolchain using a compounding method.

Results/Discussion

Realistic B-mode images of the carotid artery could be simulated. Analysis of the speckle intensity distribution shows an excellent agreement with theory, as a realistic speckle intensity is achieved (**Fig 1b**). The Monte-Carlo photon simulation algorithm could be used to simulate the initial pressure field in the tissue (**Fig 1c**). The acoustic pressure field was simulated and the pressure measured at the transducer interface was used to reconstruct the PA image (**Fig 1d**). The proposed toolchain therefore successfully combined the mechanical, optical and acoustical domains. This coupling is essential to simulate time-dependent signal processing, which occurs, for instance, in motion corrected PA signal averaging.