Towards in vivo quantification of methemoglobin using photoacoustic imaging

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Background, Motivation and Objective

Diseases characterized by inflammation and oxidative stress lead to varying degrees of methemoglobin (metHb) formation which in turn is causal in development of irreversible tissue damage. Currently the concentration of metHb can only be quantified in vitro after extraction of a blood/fluid sample. An accurate non-invasive measure of methemoglobin formation in vivo would be of great clinical diagnostic and therapeutic value. We recently acquired a high frequency photoacoustic/ultrasound system (Vevo Lazr-X, FUJIFILM VisualSonics Inc., Toronto, ON, Canada) with a tunable laser within the 680-970 nm range. The objective of this study was to derive a spectral unmixing approach that could quantify the amount of metHb within the available photoacoustic wavelength range.

Statement of Contribution/Methods

As a first step, different concentrations of metHb (0, 20, 40, 60, 80, 100 %) compared to oxidized hemoglobin (oxyHb) were diluted in water and measured with collimated transmission spectroscopy (CTS) using deionized water as reference. There was no spectral peak that distinguished metHb from oxyHb within 680-970 nm, the respective spectrums were very similar and matched those reported in the literature. However, certain derivatives were found useful. Specifically, a combination of the wavelengths 702, 718, 759, 775 and 832 nm was found to effectively quantify the amount of metHb compared to oxyHb (and also Hb based on spectrums from literature).

Results/Discussion

Figure A shows the relative absorption curves acquired when the samples were diluted to 20% compared to water. Figure B shows the outcome of the suggested spectral unmixing vs the amount of metHb compared to oxyHb. The results are based on the measurements made in this study (metHb + oxyHb). However, it should be noted that, based on well-known spectrums from literature, also deoxygenated hemoglobin (Hb) was considered in the spectral unmixing. The wavelengths were chosen in such a way that the contributions from oxyHb and Hb are equal and thus the relative concentration between oxyHb and Hb does not matter. The results indicate an effective approach to assess metHb within the available 680-970 nm range. This is an important first step towards quantifying metHb noninvasively in vivo using photoacoustic imaging.

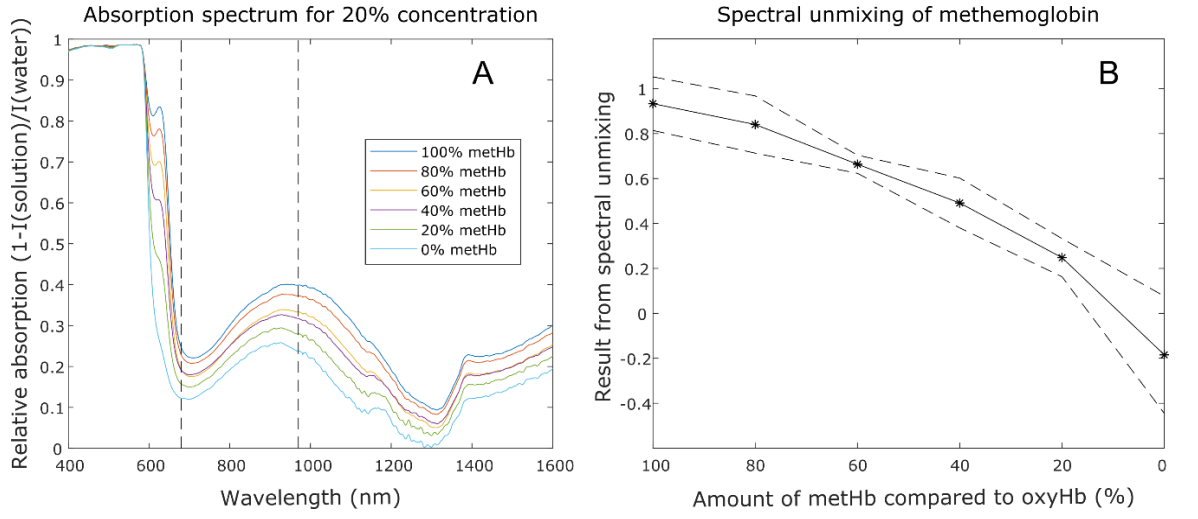

Figure A. *The measured absorption spectrums for different relative solutions of methemoglobin (metHb) and oxidized hemoglobin (oxyHb) diluted to 20% in water. The available photoacoustic wavelengths are between the dashed lines.*
Figure B.*The proposed spectral unmixing applied on different relative solutions of metHb and oxyHb. Solid line is the mean of four different concentrations of the solutions compared to water. Dashed lines are the mean plus/minus one standard deviation. (one outlier at 40% is removed)*