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Optoacoustic Characterization of Hepatic and Renal Vasculature

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Optoacoustic (OA) imaging is being investigated as a non-invasive technique to characterize tissue microvasculature. The technique involves exposing tissues to nanosecond pulsed near infrared laser light. The optical energy is absorbed by tissue chromophores (eg hemoglobin) and converted into heat, leading to thermoelastic expansion, and the production of acoustic waves. The generated acoustic waves are in the ultrasonic frequency range and are detected by transducers positioned outside the body. The intensity and frequency of the OA signals is dependent on the concentration and size of the absorbers, respectively. As such, interpretation of OA signals/images relies on knowledge of the vasculature architecture such as vessel diameter, density and branching ratios, which differ in tumour compared to healthy normal tissues.

In this study, murine hepatic and renal normal vascular architectures were generated using a vascular casting method. All procedures performed were conducted in accordance with the guidelines of the Canadian Council for Animal Care. A casting solution of methyl methacrylate (Mercox®) with benzoyl peroxide (catalyst) was prepared and injected into the left ventricle. The soft tissue was then removed using sodium hydroxide (40%). The casts were cleaned and embedded into a gelatin matrix prior to OA imaging. Casts were imaged using a reverse-mode optoacoustic imaging system (Seno Medical, San Antonio, TX) consisting of a 775 nm laser and an 8-element annular transducer array with a central frequency of 5 MHz. Three mice were used in the study for a total of 3 hepatic casts and 6 renal casts. Optoacoustic signals were acquired in a 2 by 2 mm ROI centered on each cast.

Integrated OA signal amplitude values for the hepatic and renal vascular casts yielded no significant differences. However optoacoustic frequency spectral analysis, carried out by applying a linear fit to the calibrated power spectra, demonstrated a significant difference ($p<0.001$) in the midband fit (dB), slope (dB/MHz) and intercept (dB) values between the renal and hepatic casts. All three linear fit metrics were higher for the hepatic casts compared to the renal casts. The higher midband fit and slope observed for hepatic casts is associated with increased vessel density and decreased vessel size, compared to the renal casts, which agrees with the literature on these vascular architectures. The results demonstrate the ability of OA imaging to discriminate between different vascular architectures. Furthermore, frequency spectral analysis of OA signals can provide sub-resolution details about relative vessel size in the imaging field of view.

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