Distinguishing muscle hypertrophy in intestinal strictures: a feasibility study.

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BACKGROUND

- Inflammatory bowel disease (IBD) is a chronic autoimmune disease that causes obstructing intestinal strictures. The accurate characterization of inflammation, fibrosis, and muscular hypertrophy conditions in the intestinal strictures is critical for the management of IBD.
- In this study, we investigate the feasibility of resolving the muscle component, which is characterized by its rich myoglobin content, in intestinal strictures.

METHOD

- Photoacoustic imaging (PAI) is sensitive to absorbents, such as hemoglobin and myoglobin. We can use spectral unmixing method to resolve different biological contents based on Beer-Lambert law.

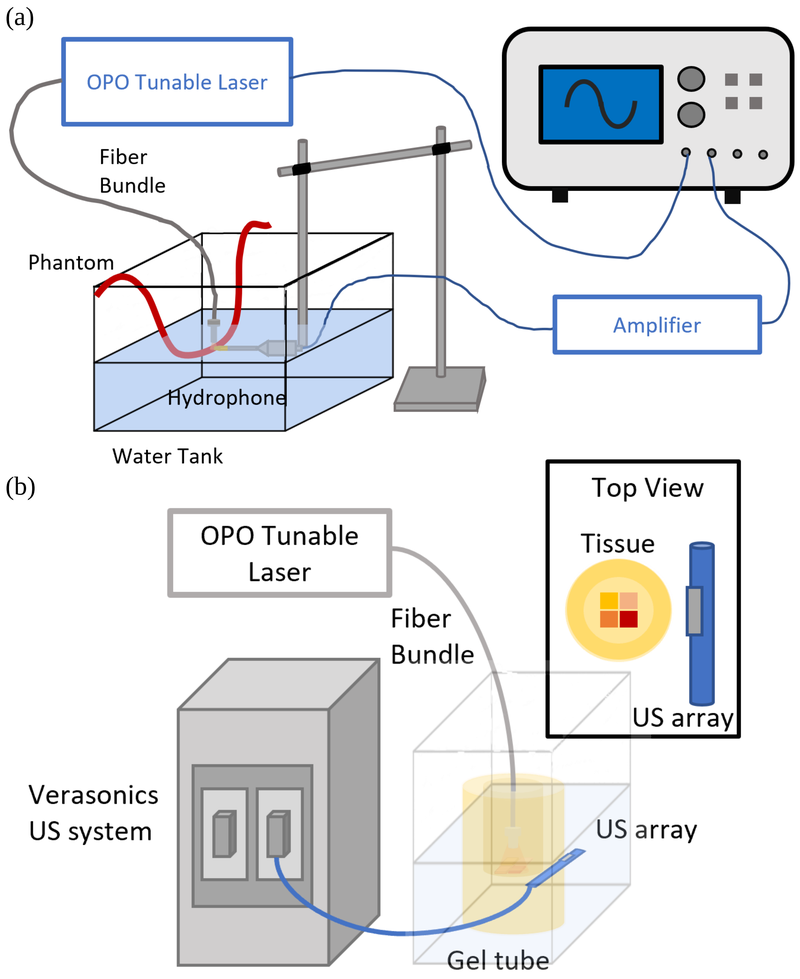

Fig 1. (a) OPO tunable laser (Phocus Mobile, OPOTEK, Santa Clara, CA) and hydrophone (bandwidth: 1-28 MHz, Onda HNC series). Phantom samples are myoglobin/hemoglobin (Mb/Hb) solutions at controlled concentrations, injected into a clear tube (Nordson Medical). (b) OPO tunable laser and a catheter US array probe (Acunav 8F, Siemens, Seattle, WA). Tissue samples are beef, beef with blood injected, fat and tendon.

- Different biological contents can be resolved by spectral unmixing method based on Beer-Lambert law: $A = \epsilon bC$, where A is absorbance, ϵ is molar attenuation coefficient or absorptivity, b is optical path length and C is concentration.
- To resolve multiple concentrations, we can use matrix form:

$$\begin{bmatrix} C_{Hb} \\ C_{Mb} \end{bmatrix} = \begin{bmatrix} \mu_{Hb\lambda_1} & \mu_{Mb\lambda_1} \\ \mu_{Hb\lambda_2} & \mu_{Mb\lambda_2} \end{bmatrix}^{-1} \times \begin{bmatrix} A_{\lambda_1} \\ A_{\lambda_2} \end{bmatrix}$$

RESULTS

Phantom study results

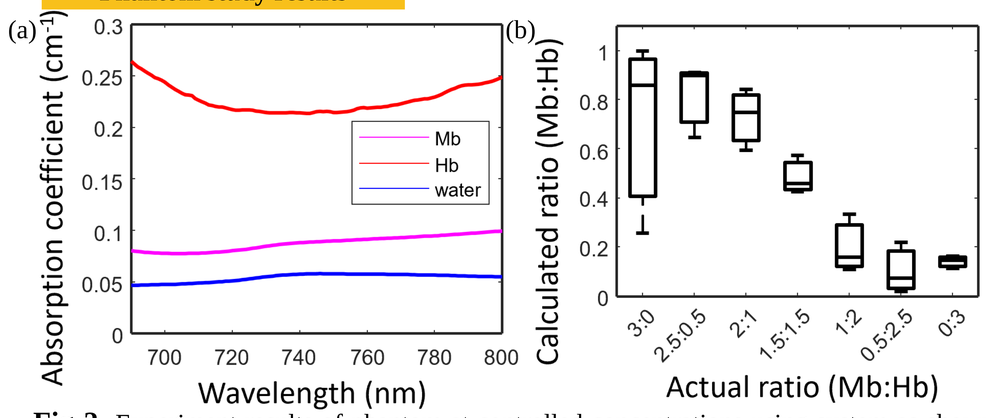

Fig 2. Experiment results of phantom at controlled concentrations using system as shown in Fig. 1a. The phantom samples are from lyophilized myoglobin powder from equine heart and hemoglobin powder from bovine blood. Wavelengths are swept at 690 nm, 734 nm, 757 nm and 800 nm. (a) Absorption coefficients of hemoglobin (Hb), myoglobin (Mb) and water measured by spectrometer (SpectraMax M2, Molecular Devices, San Jose, CA). (b) Calculated ratios of Mb:Hb versus actual ratios of Mb:Hb. R-squared: 0.673.

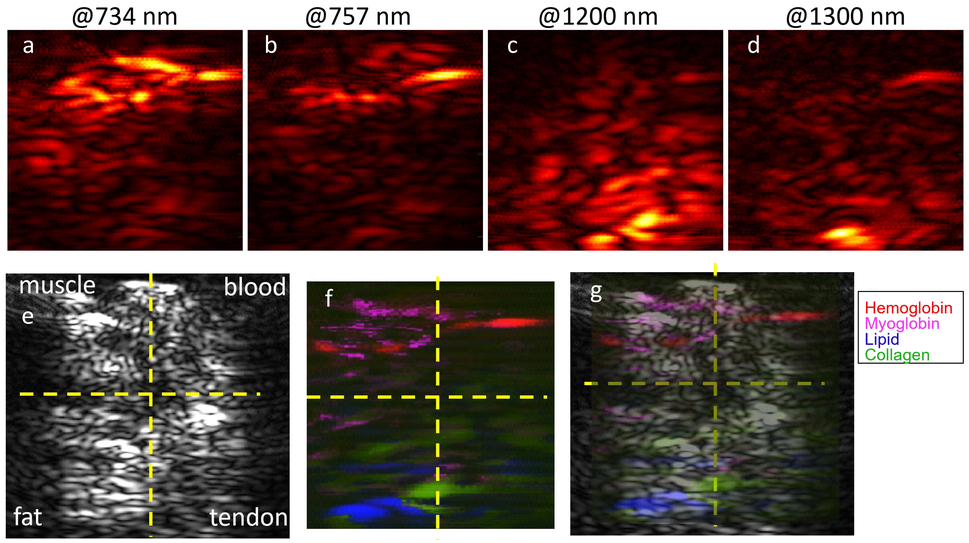

Fig 3. Imaging results using Verasonics ultrasound imaging system as shown in Fig. 1b. (a-d) Photoacoustic imaging results of tissue phantoms at wavelengths of 734 nm, 757 nm, 1200 nm and 1300 nm, respectively. (e) Ultrasound image of tissue phantoms. (f) Resolved Hb (in red), Mb (in pink), lipid (in blue) and collagen (in green) which are the main composition of blood, beef, fat and tendon. (g) Ultrasound image merged with resolved photoacoustic signals of Hb, Mb, lipid and collagen.

Rabbit in-vivo results

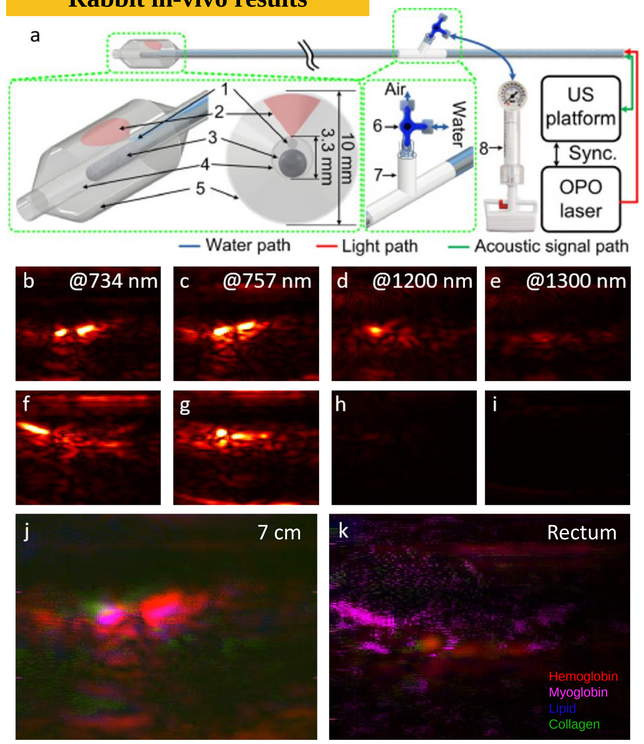

Fig 4. In-vivo imaging system and results of rabbit colon. (a) The assembly of balloon catheter. 1) Side-firing fiber optics with 800 μm core. 2) Illumination delivered by the side-firing fiber optic. 3) US array. 4) Semi-rigid tube to hold the relative positions of the side-firing fiber and the US transducer. 5) Hydrostatic balloon. 6) Three-way stopcock. 7) T adapter. 8) Hydrostatic pump. (b-i) Photoacoustic images at different wavelengths. (j-k) Resolved tissue components of 7cm location and rectum.

Discussion & conclusion

- We have explored our feasibility of resolving different concentrations of myoglobin solutions and hemoglobin solutions and the feasibility of resolving multiple tissue samples.
- We used the endoscopic photoacoustic ultrasound imaging balloon catheter to image the rabbit colon in-vivo. Rectum has more muscle components than colon, as expected.
- Our spectral unmixing method successfully characterized the vasculature and the muscle components.
- Further investigation to resolve acute inflammation, fibrosis and muscle hypertrophy in human tissue samples are ongoing.