Ultrasound-mediated Scavenging of Dissolved Oxygen

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MOTIVATION & OBJECTIVE
- Excess dissolved gases in blood can affect tissue health. Reactive oxygen species produced during reoxygenation following an ischemic event can significantly increase infarct volume (Murray 1996, Zorov 2014).
- Current treatments employ systemic administration of a therapy, which can have deleterious off-target effects.
- The objective of this study is to demonstrate gas scavenging using acoustic droplet vaporization (ADV).

BACKGROUND
ADV is the ultrasound-mediated conversion of a liquid perfluorocarbon droplet emulsion into gas microbubbles (Figure 1). The conversion only occurs when the ultrasound pressure amplitude exceeds a threshold value.

METHODS
- To create size-isolated droplets, the emulsion was differentially centrifuged (Feshitan 2009).
- Droplets were flowed through a vessel phantom that includes dissolved oxygen (DO) sensors (Figure 3).
- Droplets were soninified with 2 MHz ultrasound at 0 MPa (no ultrasound), 1 MPa (sub-threshold), 3 MPa (super-threshold), and 5 MPa (super-threshold).
- The dissolved oxygen was measured upstream and downstream of the ultrasound sononation location.
- The effluent was measured to determine the droplet size distribution and conversion fraction (Figures 3 and 4).

RESULTS
- Volume-weighted number density size-distributions for size-isolated droplets in saline (left) and corresponding changes in DO (right). Differential centrifugation increased the fraction of droplets between 2 μm and 5 μm from 29% to 93%. A model based on the hypothesized mechanism and droplet conversion fraction agreed with the experimental measurements.

DISCUSSION & IMPACT
- Ultrasound-mediated conversion of perfluorocarbon droplets into gas microbubbles scavenges dissolved oxygen.
- Oxygen scavenging was observed in saline and whole blood.
- A numerical model based on concentration gradients accurately predicted the amount of gas scavenged, implying the mechanism of scavenging is the diffusion of dissolved gases from the fluid and into the microbubbles.
- Differential centrifugation isolated droplets between approximately 2 μm and 5 μm.
- Next steps include measuring gas scavenging kinetics and the efficacy for reducing reactive oxygen species production.

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