Sono-Photoacoustic Activation of Polypyrrole Coated Nanodroplets for Thrombolysis

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Background, Motivation and Objective

Phase-change contrast agents are liquid perfluorocarbon (PFC) droplet based contrast agents that can be selectively vaporized using a sufficiently high intensity acoustic pulse or through photothermal heating. They can be easily synthesized with diameters under 200 nm, enabling efficient diffusion into diseased tissues. In many cases, the thresholds for droplet activation using optical or acoustic energy alone exceeds ANSI or FDA limits. Sono-photoacoustics (SPA) uses simultaneous photothermal and acoustic energy to activate droplets. By carefully timing a laser and ultrasound pulse such that the optical pulse arrives during the peak rarefactional phase of the acoustic pulse at the region of interest, activation thresholds can be dramatically reduced (by up to two orders of magnitude). In this study, we demonstrate that SPA activation of polypyrrole coated nanoemulsions can be used for thrombolysis.

Statement of Contribution/Methods

SPA thrombolysis was demonstrated in a fibrin clot model. 4 mm diameter fibrin clots 2-3 cm in length were formed in polyethylene tubing. A water column with approximately 40 cm H_2O of hydrostatic pressure was used to simulate pressure driven flow commonly found in clots formed in fistulas. The degree of occlusion was quantified by monitoring the flow rate exiting the clot with a digital balance. Clots treated using a mechanically scanned 1.24 MHz spherically focused transducer were compared with those treated with an electronically steered linear array transducer (ATL L7-4 operating at 5.2 MHz).

Results/Discussion

Flow was restored in fibrin clots only when cavitation was detected. Although droplet activation was detected at optical fluences as low as 2 mJ/cm^2 and an acoustic pressure of 1.1 MPa, increased acoustic pressure was needed to effectively treat the clot. Above-threshold pressures are likely needed to break down the clot by mechanically driving resultant bubbles to erode it.

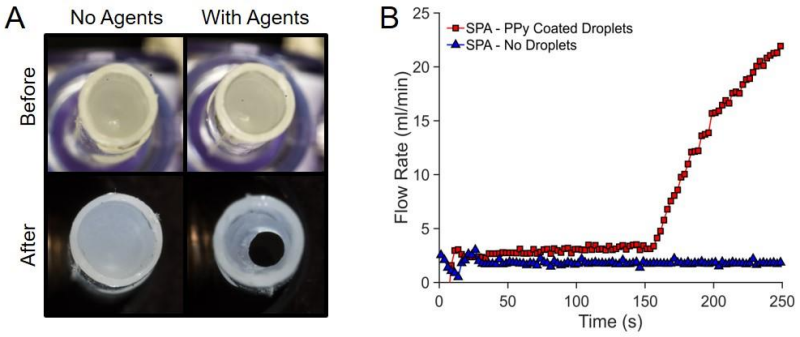

Figure 1: (A) Cross-sectional views comparing fibrin clots before and after sono-photoacoustic treatment with and without polypyrrole (PPy) coated perfluorobutane droplets. Both samples were treated using a peak pressure of 2.5 MPa (MI = 1.77) and an optical fluence of 4.2 mJ/cm^2. (B) Flow was restored 157 seconds after beginning sono-photoacoustic thrombolysis with the PPy coated droplets.