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Transurethral light delivery for photoacoustic imaging of porphysome contrast agent in the prostate: Evaluation in a tissue mimicking phantom

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Background, Motivation and Objective

Prostate cancer (PCa) is a focal disease that has the potential to be successfully treated with focal or targeted therapies. However, these treatment approaches need accurate index lesion delineation and real-time image guidance. We are investigating photoacoustic (PA) imaging combined with a transrectal micro-ultrasound (micro-US) as a means of achieving both high optical contrast and high spatial resolution for guiding focal therapies in the prostate. Prior work indicated deeper illumination is required to obtain useful PA images of the prostate. The PA image can also be enhanced with improved imaging depth and by using PA contrast agents, for example organic porphyrin-lipid porphysome (PS) nanoparticles that have enhanced uptake in tumours. Here we introduce and evaluate a transurethral (TU) illumination system combined with PS contrast agents for improved PA imaging depth in the prostate.

Statement of Contribution/Methods

Side-fire TU optical fiber tip has been designed to illuminate the prostate from the urethra in large animal disease models. A 1.5 mm core multimode optical fiber was flat cleaved and polished with at right angled prism to divert the light at 90º and held in a 5 mm diameter case (Fig 1A). A tunable (680 to 970 nm) laser (Vevo LAZR, VisualSonics, Toronto, Canada) was coupled into the TU fiber. The fiber was evaluated with a cylindrical PVC-Plastisol prostate mimicking phantom with optical absorbers and acoustic scatterers (Fig 1B); the fiber was placed in the center of the lumen mimicking the urethra. Polyurethane (PUR) tubes were inserted at up to 15 mm radially from the central lumen, approximating the distance between urethra and rectum, and filled with 35 µM -135 µM solution of PS contrast agent. A commercial 256-element, 20 MHz micro-US array was used for PA mode receive and B-mode image acquisition. The acquired PA signal was spectrally unmixed to separate PS from other optical absorbers in the phantom.

Results/Discussion

In air, the TU fiber generated 160 mJ/cm^2 fluence at 2 mm with an input laser pulse energy of 5mJ. PA and B-mode images localized PS contrast to all PUR tubes for contrast agent concentration > 135 µM (Fig 1C: 135 µM at ~10 mm from the lumen). We were able to detect 35 µM concentration at 10 mm but SNR at lower concentrations needs more investigation and optimization of the phantom. These results are promising for TU illumination of the prostate and future translation to imaging PS nanoparticles in tumours to delineate lesions for focal therapy.

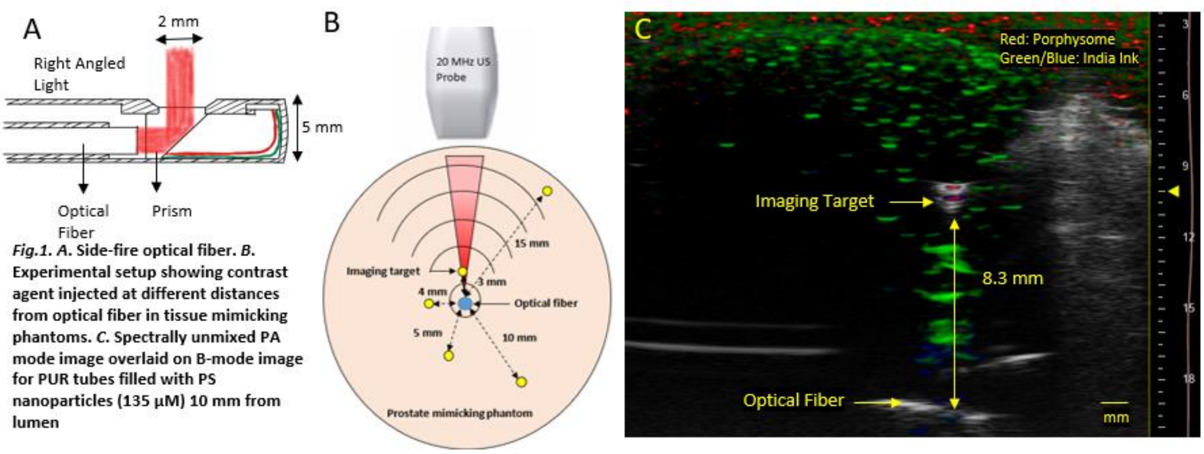

Fig.1. A. **Side-fire optical fiber. *B.* Experimental setup showing contrast agent injected at different distances from optical fiber in tissue mimicking phantoms. *C.* Spectrally unmixed PA mode image overlaid on B-mode image for PUR tubes filled with PS nanoparticles (135 µM) 10 mm from lumen**