Optical Transport and Spectroscopic Properties of a Canine Prostate from Ex Vivo Interstitial Radiance Measurements

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Abstract

Canine prostate is a close match for human prostate and is used in research of prostate cancers. Determining accurately optical absorption and scattering properties of the gland in a wide spectral range (preferably in minimally invasive way), linking optical properties to concentrations of major endogenous chromophores and detecting the presence of localized optical inhomogeneities like inclusions of gold nanoparticles for therapeutic and diagnostic purposes are among major challenges for researchers. The goal of this work is to demonstrate a feasibility of the multifunctional radiance spectroscopy platform in providing the required information. For ex vivo canine prostate, extraction of the effective attenuation and the diffusion coefficients using relative cw radiance measurements was demonstrated in 650-900 nm range. The derived absorption coefficient was decomposed to contributions from 9.0 μM HbO2, 29.6 μM Hb and 0.47 fractional volume of H2O. Detection of a localized inclusion containing ~1.5-1010 gold nanorods (0.5, 8 μg Au) at 10 mm distance from the urethra was achieved with the detector in the urethra and the light source in a virtual rectum position. The platform offers the framework for a systematic study of various chromophores in the prostate that can be used as comprehensive diagnostic markers.

Introduction

Canine prostate is considered to be the best model for the human prostate cancer even though there is no implanted prostate cancer model in dogs and most studies are done on the benign prostate. It is often used for evaluation of prostate ablative techniques like PDT (photodynamic therapy) and thermal therapy. The main purpose of measuring optical properties of the canine prostate has been mainly for treatment planning and monitoring during PDT. Absorption and scattering properties of the tissue determine the light fluence distribution in the largest volume. Usually, measurements of optical properties are carried at a wavelength of light at which the treatment is performed. Employing spectroscopic measurements as opposed to a single wavelength has been an increasing trend in oncology. It was demonstrated that near-infrared spectroscopy can be used as noninvasive or minimally invasive diagnostics of cancer by analyzing differences of endogenous chromophores (oxyhemoglobin, deoxyhemoglobin, water, etc.) between normal and malignant tissues.

Gold nanoparticles (Au NPs) offer a number of promising applications in nanomedicine of prostate cancers: interstitial nanoparticle-mediated laser thermal therapy, enhanced radiation sensitivity and toxicity in prostate cancer cells containing Au NPs and brachytherapy implants of radioactive 198Au. NP-placed into the gland to deliver the radiosurgical dose directly to the tumor site. Au NPs can be also used for delineation of cancer regions by targeting cancer bio-markers that are over expressed in the gland (PSMA, for example) and then be imaged with either established clinical imaging modalities like CT or optical techniques like radiance spectroscopy which is the enabling approach in the current work.

In the current work, we demonstrate the platform that 1) is applied to the canine prostate ex vivo and can be potentially in vivo, 2) performs minimally invasive optical interrogation of the gland, 3) quantifies absorption and scattering properties of the prostate in a wide spectral range, 4) links the optical absorption coefficient to contributions of major chromophores and 4) identifies spectroscopically and locates in the angular domain a localized optical inhomogeneity composed of Au NPs embedded in the canine prostate.

Experimental

Canine prostate sample. A canine prostate (Labrador retriever, intact male, 10-12 years, 26 kg) was harvested at the Atlantic Veterinary College, University of PEI as per Animal Control and Biosafety protocol approved by the University. The urinary bladder and proximal urethra, extending the length of the pelvic cavity and including the prostate, were removed. The ureters were transected several cm from the trigone, and urine was expressed from the bladder. Collection of the prostate was done 4 hours after euthanization. The largest dimension of the prostate was ~40 mm. The optical measurements began approximately 17 hours after collection. The prostate was never frozen before or between the measurements.

Conclusion

The multifunctional radiance-based optical platform offers the framework for a systematic ex vivo study of major chromophores in the canine and potentially, in vivo human prostate that can be used as comprehensive diagnostic markers in determining the state of the prostate health. The detected number of Au NPs in the prostate approaches the target of ~1010 that may favor early cancer detection in the prostate.

References