Characterization of optical clearing mechanisms in kidney tissues: discrimination of clear cell renal cell carcinoma

Maria R. Pinheiro[1,2], Maria I. Carvalho[1,2], Valery V. Tuchin[3,4], Luís M. Oliveira[1,5]

1- Institute for Systems and Computer Engineering, Technology and Science (INESC TEC), Campus da FEUP, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

2- Department of Electrical and Computer Engineering, Faculty of Engineering of Porto University (FEUP), Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

3- Institute of Physics and Science Medical Center, Saratov State University, 83 Astrakhanskaya str., Saratov 410012, Russian Federation

4- Laboratory of Laser Diagnostics of Technical and Living Systems, Institute of Precision Mechanics and Control of the FRC "Saratov Scientific Centre of the Russian Academy of Sciences," 24 Rabochaya, Saratov 410028, Russian Federation

5- Physics Department, School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida nº 431, 4249-015 Porto, Portugal

Main author email address: maria.r.pinheiro@inesctec.pt

The optical immersion clearing technique reduces light scattering in tissues and related studies have previously allowed the detection and characterization of pathologies such as cancer [1]. Characterizing the diffusion of water and of the optical clearing agent (OCA) during tissue immersion treatments is essential to understand the underlying mechanisms of tissue clearing. The two main mechanisms, commonly designated as tissue dehydration and refractive index (RI) matching, are directly associated to the water and OCA fluxes in the tissues [2].

This study evaluated the diffusion properties of water and sucrose in human kidney tissues, both healthy and with clear cell carcinoma, the most common subtype of kidney cancer. Kinetic collimated transmittance (T_c) spectral measurements were performed from kidney samples immersed in water-sucrose solutions of different osmolarities. The characteristic diffusion times (τ) of sucrose were estimated from these measurements as 334.8 s and 382.0 s for healthy and tumorous tissues, respectively, while the corresponding diffusion times of water were 60.5 s and 60.0 s.

In addition to the kinetic T_c spectral measurements, sample thickness measurements were also performed during treatments characterized by unique sucrose and water fluxes, allowing to calculate the diffusion coefficients (D) of water and sucrose in the healthy kidney as 1.39×10^{-6} cm^2/s and 3.06×10^{-7} cm^2/s, and in the tumorous tissue as 1.06×10^{-6} cm^2/s and 2.15×10^{-7} cm^2/s.

These findings provide cancer-discriminating parameters that may support the differentiation and optical characterization of healthy and tumorous kidney tissues.

[1] V. V. Tuchin, D. Zhu and E. A. Genina, Handbook of Tissue Optical Clearing: New Prospects in Optical Imaging, Boca Raton, FL, USA: CRC Press, 2022, doi: 10.1201/9781003025252.

[2] L. M. C. Oliveira and V. V. Tuchin, The Optical Clearing Method – A New Tool for Clinical Practice and Biomedical Engineering. Cham, Switzerland: Springer International Publishing, 2019. doi: 10.1007/978-3-030-33055-2.