

Application of optical spectroscopy in minimally invasive surgery

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Minimally invasive surgery (MIS) is a rapidly evolving field that requires the development of new technologies to provide diagnostic information about the condition of the organs being operated on. Optical spectroscopy methods offer information on metabolic processes, perfusion and morphological structure of tissues and can be combined with standard surgical instruments.

The team of the R&D Center of Biomedical Photonics (Orel State University) has been engaged in the development and implementation of optical spectroscopy devices for MIS for several years. This work presents the application of the developments for MIS in preclinical and clinical practice.

The techniques were developed to differentiate between healthy parenchyma of the liver and tumor during liver percutaneous biopsy using an optical fine needle probe compatible with standard Chiba 17.5G biopsy needles. Two optical biopsy systems were proposed: 1) multimodal optical percutaneous needle biopsy system including fluorescence spectroscopy (FS) and diffuse reflectance spectroscopy (DRS) channels [1]; 2) fluorescence lifetime optical biopsy based on a TCSPC approach [2]. In preclinical and clinical studies, high diagnostic accuracy was achieved in differentiating between healthy liver and tumor. The sensitivity and specificity of the multimodal biopsy system reached 0.90 and 0.95, and those of the fluorescence lifetime optical biopsy system reached 0.90 and 1.0 respectively. Parameters such as the fluorescence lifetime of metabolic co-enzymes of free NADH and protein-bounded NAD(P)H have great potential for distinguishing different types of cancer.

Obstructive jaundice is a group of diseases of the biliary system characterized by obstruction of the bile ducts leading to hepatocyte dysfunction and impaired functional state of the liver. The optical percutaneous needle biopsy system allows to record FS spectra of the liver of patients with obstructive jaundice during preoperative biliary drainage. Clinical studies demonstrated a statistically significant increase in the contribution of NAD(P)H, bilirubin, flavins and vitamin A fluorophores in the liver tissue of patients with obstructive jaundice. These parameters may be used as promising prognostic markers for determining the development of liver failure [3].

Laparoscopic myomectomy is the method for surgical treatment of symptomatic uterine myomas. A special probe was developed to record FS and laser Doppler flowmetry signals through laparoscopic accesses. We found that myomas have different blood supply and fluorescence levels depending on their growth intensity and size. The ability of laser Doppler flowmetry to assess endometrial perfusion is also demonstrated to investigate the effect of myomas of different types on endometrial tissue blood supply. The results obtained can be used to provide a better understanding of pathological processes in uterine leiomyomas, thus helping physicians to select treatment strategies [4].

Optical spectroscopy provides a wide range of diagnostic capabilities for clinical applications in a variety of MIS fields.

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