Percutaneous Nephrostomy Guidance by a Polarization-Sensitive Optical Coherence Tomography Probe

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100 words:

Percutaneous nephrostomy (PCN) is a minimally invasive procedure used in kidney surgery. PCN needle placement is of great importance for the following successful renal surgery. In this study, we designed and built an endoscopic polarization-sensitive optical coherence tomography (PS-OCT) system for the PCN needle guidance. Compared to traditional OCT, PS-OCT will allow more accurate differentiation of the renal tissue types in front of the needle. In the experiment, we imaged different renal tissues from human kidneys using the PS-OCT endoscope. Furthermore, deep learning methods were applied for automatic recognition of different tissue types.

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Percutaneous nephrostomy (PCN) is a minimally invasive procedure for the access to kidney collecting system. A PCN needle needs to be inserted into the renal pelvis to establish a route for surgical procedures such as removing the kidney stones. It has been widely used, but accurate needle placement remains challenging. Unsuccessful needle insertion leads to damage to the normal tissue, resulting in complications like urine leak, hemorrhage, sepsis, etc. Therefore, imaging modalities are required for PCN needle guidance. Currently, conventional methods like ultrasound or computed tomography (CT) have been applied, but the imaging resolutions are limited. Therefore, an imaging method which can provide more accurate needle guidance is needed. Optical coherence tomography (OCT) is a biomedical imaging modality that has high spatial resolution (~10 μm). Compared to the conventional structural OCT, polarization-sensitive optical coherence tomography (PS-OCT) provides more imaging information based on the diattenuation and birefringence phenomena of tissue. In this study, we developed a forward-viewing endoscopic PS-OCT probe which can help enhance the contrast of the tissues ahead of the PCN needle. Different renal tissues from human kidneys including cortex, medulla, calyx, and renal fat were imaged by our PS-OCT probe. Those tissues showed different imaging features, and the PS-OCT probe performed better in the tissue recognition compared to intensity OCT. Furthermore, we utilized deep learning methods to automate the tissue identification. Convolutional neural networks (CNNs) were applied to automatically classify the different renal tissues, and over 95% of the accuracy has been achieved.