Feasibility of Using Polarization-Sensitive Optical Coherence Tomography (PS-OCT) in Epidural Anesthesia Guidance

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Guidance of epidural needle is important for the safe and efficient epidural anesthesia procedure. In this study, we built an endoscopic system based on polarization-sensitive optical coherence tomography (PS-OCT). We used pig backbones to test the feasibility of our PS-OCT endoscopic system. Different spinal tissue layers that epidural needle punctures through including subcutaneous fat, ligament, ligamentum flavum, epidural space and spinal cord were imaged and analyzed. They showed different imaging features on the PS-OCT imaging results. Furthermore, we applied deep-learning methods to classify those tissue types automatically to improve the recognition efficiency.

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Epidural anesthesia is a well-established pain-relief method. During that, a needle is used to inject the anesthetic medications to the epidural space inside the backbone. The epidural needle penetrates subcutaneous fat, ligament, ligamentum flavum before ~~arriving~~ reaching the epidural space. Accurate positioning of the epidural needle is critical for safe and effective anesthesia. Inadvertent needle insertion leads to unsuccessful anesthesia and damage to the spinal cord. Failure rate of the needle insertion can reach 20% and it can lead to severe complications. Currently used traditional methods cannot accurately guide the needle tip. In our previous research, we developed a forward-viewing optical coherence tomography (OCT) endoscope to help guide the epidural needle. However, classification of the different tissue types through the structural OCT alone still needs improvement. Polarization-sensitive optical coherence tomography (PS-OCT) will allow more accurate tissue identification in the spine, because spinal tissues, such as ligaments and nerves, contain highly organized and directional micro-structures, which can result in strong polarization contrast. In this study, we developed an endoscopic PS-OCT system and tested it on pig backbones. Different spinal tissues including subcutaneous fat, ligament, ligamentum flavum, epidural space and spinal cord were imaged to mimic the practical condition. This PS-OCT probe performed better in the tissue recognition compared to intensity OCT. Furthermore, to reduce the learning burden of the operators, we utilized deep learning methods to automate the tissue identification. Convolutional neural networks (CNNs) were applied to automatically classify the different spinal tissues, and over 80% of the accuracy has been achieved.