Label-free nerve imaging with coherent anti-Stokes Raman scattering rigid endoscope by improving imaging speed with deep learning

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Injury of peripheral nerves in surgery should be avoided to improve the prognosis of patients. An apparatus is demanded to identify the nerves since the nerve fibers are not recognized with naked eyes or magnifying endoscopy. We have developed a coherent anti-Stokes Raman scattering (CARS) rigid endoscope to visualize the nerves with label-free [1]. Nerve fibers in rabbit prostate fascia are visualized with the developed endoscope. The exposure time for a few minutes per image must be shortened to introduce the CARS endoscope to medical settings.

We employ noise reduction with deep learning to improve the speed of CARS imaging. A deep learning model is trained to restore an image with a high signal-to-noise ratio (SNR) for long exposure time from an image with a low SNR for short exposure time. Training for deep learning requires thousands of orders of data: however, obtaining nerve images at the order with the CARS endoscope is time consuming. CARS microscopy images are utilized as a pre-training dataset. The reason is that a large dataset can be prepared faster and more easily than CARS endoscopy. Noise2Noise model [2] is pre-trained with 91×50 CARS microscopy images and is fine-tuned with 5×50 CARS endoscopy images. The exposure times of the input images are 1.8 and 4.8 seconds, respectively.

The accuracy of the restored images is evaluated by Peak signal-to-noise ratio (PSNR) and Structural Similarity (SSIM), which is used to evaluate a degree of similarity from ground truth images. The nerve images obtained for 160 seconds are utilized as the ground truth images. The averaged metrics over the five test images are 30.51 (PSNR) and 0.7184 (SSIM), respectively. The equivalent exposure time of the restored images is 36.7-42.0 seconds, which is estimated from the relationship between each metric and the exposure time. The imaging speed is improved 7.6-8.8 times faster with noise reduction by deep learning.

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