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Intraoperative Hyperspectral Imaging extending Optical Imaging of stimulated active brain areas in neurosurgery – a feasibility study

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Introduction

Hyperspectral Imaging (HSI) is a method that was commonly used in the past for optical remote sensing in aerospace or waste separation. It is a noninvasive and contact-free method which operates without additional markers. Due to recent technological advancement HSI can be used today for a wide variety of classification tasks. One of the most promising field of application is the tissue differentiation in neurosurgery. Compared with other optical analysis methods that operate with two to twelve distinct wavelength bands (e.g. pulse oximetry), hyperspectral imaging allows the evaluation and analysis of more than one hundred wavelengths in an almost continuous spectrum. Furthermore a major advantage of hyperspectral imaging is the high spatial resolution over larger areas.

Methods

Clinical Setup

Because of the small size and the C-Mount thread of the HSI camera (TI-Cam, Diaspective Vision GmbH, Salzhaff/Pepelow, Germany) it can be used in neurosurgical operating room without any remarkable changes. During a surgical procedure the camera is attached to a microscope (OPMI Pico, Carl Zeiss Meditec AG, Jena, Germany) (figure 1).

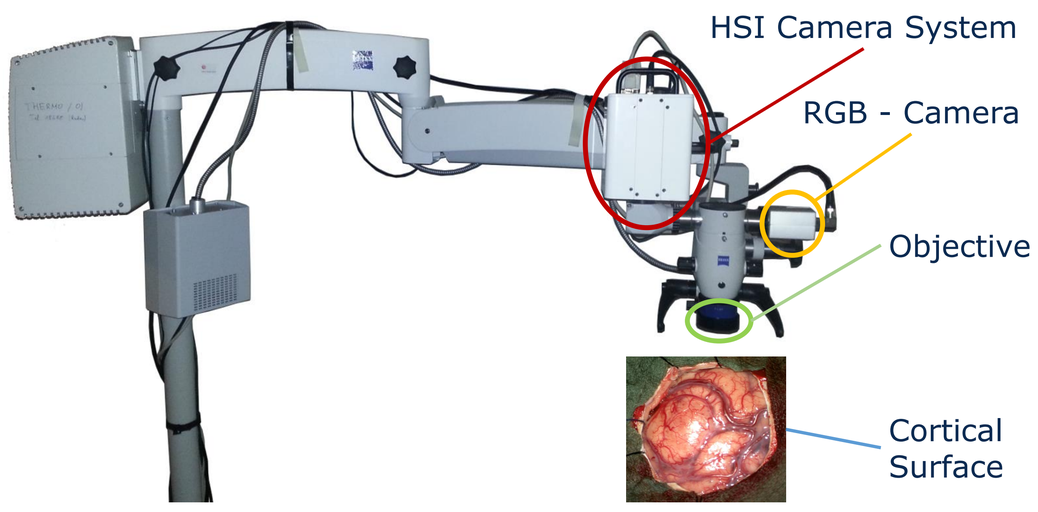

Figure 1: clinical hyperspectral image recording system.

For reasons of an easier alignment of the TI-Cam by the surgeon an RGB camera is attached to the surgical microscope via a beam splitter. The whole microscope can be protected with a conventional sterile cover. The cortical surface can be illuminated by an external light source. The light is directed via an optical fiber cable. In this case the trepanation was lighted with three 50 W halogen lamps.

HSI measurement

By use of the pushbroom slit method a line of the brain's surface can be aquired. The reflected light can be decomposed in its spectral components whilst the related spectra can be recorded with a CMOS camera.

The second spatial direction can be attained by moving the slit with the help of a stepper motor. The result of the recording of the entire trepanation is a hyperspectral datacube. This datacube includes the spectral information for each pixel of the image (figure 3, on the left). The TI-Cam covers a wavelength range between 500 nm and 1000 nm and has a spectral resolution of 5 nm.

Validation of the HSI results

In addition to the HSI-measurement the anatomy of a patient is used for validation. For this purpose preoperative gained MRI records (figure 2) or the 5-ALA fluorescence imaging are utilized. With the help of the MRI records 3D models can be created for characterizing the exact position of a tumor.

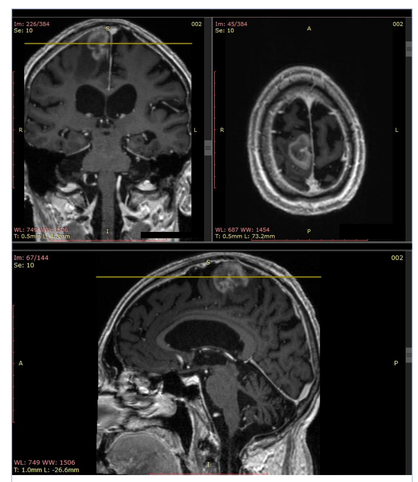

Figure 2: preoperative MRT dataset.

Results

Figure 3 shows an HSI image of a trepanation. The yellow-marked pixels highlight the glioblastoma, the red-marked pixels show the blood vessels and the blue-marked pixels highlight the sulcus. The figure on the right shows the spectra belonging to the individual regions. The spectra of all three groups can be well distinguished because of their different characteristics in various wavelength ranges.

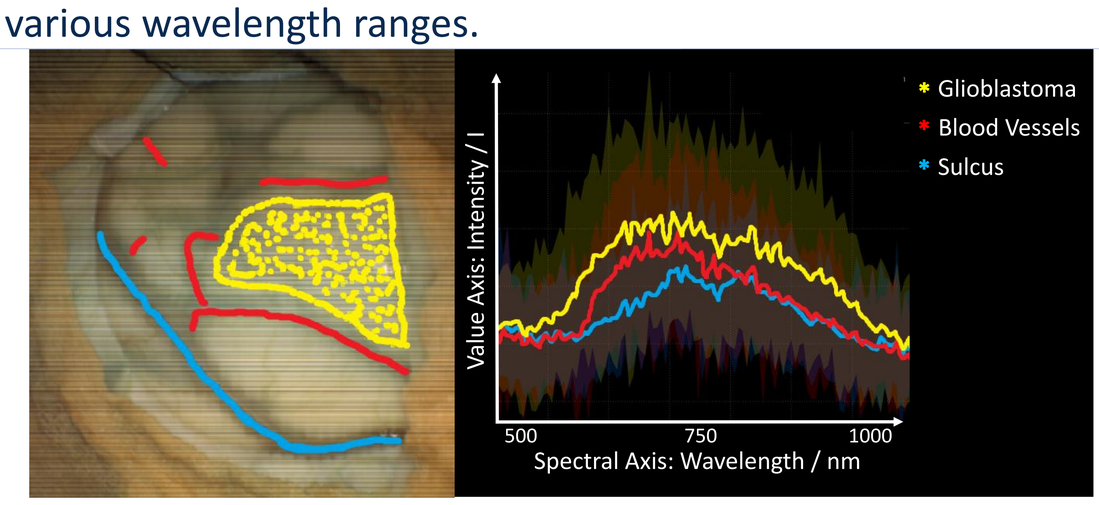

Figure 3, left side: reconstructed white light image of a glioblastoma with selected pixel groups; Fig. 3, right side: Spectra from each pixel group of figure 3, left side.

Conclusion

Hyperspectral images can be integrated in a clinical setup without any remarkable changes in the workflow. The spectra of the different tissue types show differences in significant positions whereby the condition for a classification of the different tissue types is fulfilled. At present the research mainly focusses on an efficient lighting for the clinical setup and the manufacturing of reference phantoms for preparing detailed research in intraoperatively specifying various brain issue types.

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