

Endoscopic In Vivo Hyperspectral Imaging During Routine Head and Neck Surgery

Orlando Guntinas-Lichius^{1,2}, Tammam Alamatouri¹, Ayman Bali¹, Thomas Bitter², Marcela Mafra¹, Jonas Ballmaier², Mussab Kouka², Gerlind Schneider², Nadja Ziller¹, Theresa Werner¹, David Pertzborn¹, Ferdinand von Eggeling¹, Anna Mühlig^{1,3}

¹ Clinical Biophotonics & MALDI Imaging, Department of Otorhinolaryngology, Jena University Hospital, Jena, Germany

² Department of Otorhinolaryngology, Jena University Hospital, Jena, Germany

³ Comprehensive Cancer Center Central Germany, Jena, Germany

Abstract

Head and neck cancer is the seventh most common cancer worldwide, and surgical resection requires accurate tumor margin assessment to achieve complete removal while preserving critical function. Intraoperative tumor delineation remains limited and may contribute to incomplete resection. We evaluated the feasibility of endoscopic *in vivo* hyperspectral imaging (HSI) as an intraoperative technique for real-time tumor localization in head and neck cancer surgery using a CE-certified endoscopic HSI system and a rapid spectral analysis workflow.

HSI was performed during curative tumor surgery on 12 patients with histopathologically confirmed head and neck squamous cell carcinoma (HNSCC). Imaging was conducted using a CE-certified HSI camera in an endoscopic configuration. Hyperspectral data were acquired in the spectral range of 500–1000 nm with 100 spectral bands, with an acquisition time of approximately 6 s per image. For real-time tissue visualization, calibrated reflectance data were processed using an in-house pipeline based on unsupervised spectral dimensionality reduction via principal component analysis (PCA) followed by k-means clustering to generate binary tumor/non-tumor tissue maps. Clustering results were displayed as overlays on reconstructed RGB images for immediate interpretation. Tumor classification maps were generated within <10 s, and the complete workflow added only 2–3 min of additional surgery time. The medical staff were able to use the HSI system proficiently after two surgeries. Tumor and non-tumor regions were defined by unbiased senior physicians, which served as ground truth for performance evaluation. Compared to the ground truth labels, the clustering-

based approach achieved an accuracy of 79%, a sensitivity of 72%, and a specificity of 84% for tumor localization.

These results demonstrate that endoscopic HSI can be integrated into head and neck tumor surgery with minimal additional time requirements while providing fast, quantitative intraoperative tissue visualization. The presented workflow establishes a basis for further prospective validation of HSI-supported tumor delineation and margin assessment in clinical routine.

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