Hyperspectral Imaging of Intestinal Ischemia Supported by Machine Learning

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ABSTRACT

The study focuses on developing a hyperspectral imaging (HSI) system to assess intestinal wall ischemia, which is traditionally determined visually through mesenteric vessel pulsation, peristaltic contractions, and colour assessment. These traditional methods are subjective and limited. HSI offers an objective and noninvasive alternative, combining digital imaging and spectral analysis to provide detailed information on tissue viability [1,2].

A portable imaging system was constructed on the basis of the SpecimIQ hyperspectral pushbroom camera (Specim, Spectral Imaging Ltd., Finland) providing spectral data within the total range of 400-1000 nm. A broadband illumination unit is based on the fibre-optic ring illuminator and the halogen irradiation source, providing uniform distribution of light intensity in the camera focal plane.

Animal studies were conducted on six Wistar rats, simulating ischemia by ligating the main vessels supplying the intestine. The animals were monitored at intervals of 1-, 6- and 12-hours post-ligation to assess tissue changes. Histological analyses were performed to correlate spectral data with the extent of ischemia. Tissue saturation was calculated using a two-wave approach based on the different absorption properties of oxygenated and deoxygenated haemoglobin [3], producing two-dimensional colour maps of tissue saturation.

A machine learning (ML) algorithm, specifically XGBoost, was applied to classify intestinal tissue into three categories: intact, possibly reversible ischemia, and irreversible ischemia. The model was trained on preprocessed hyperspectral data, using principal component analysis (PCA) for feature reduction. Data were labelled based on the Park/Chui histologic grading. The ML model effectively classified tissue viability with high accuracy (99%). The classification maps visually correspond to the saturation maps (Fig. 1), which indicates a high ML potential for processing raw HSI data.

The HSI system was also tested on patients with intestinal obstruction. The system successfully identified areas of reduced saturation correlating with ischemic tissue. HSI, combined with ML, offers a promising method for intraoperative assessment of intestinal viability. It provides objective, noninvasive diagnostics without contrast agents.

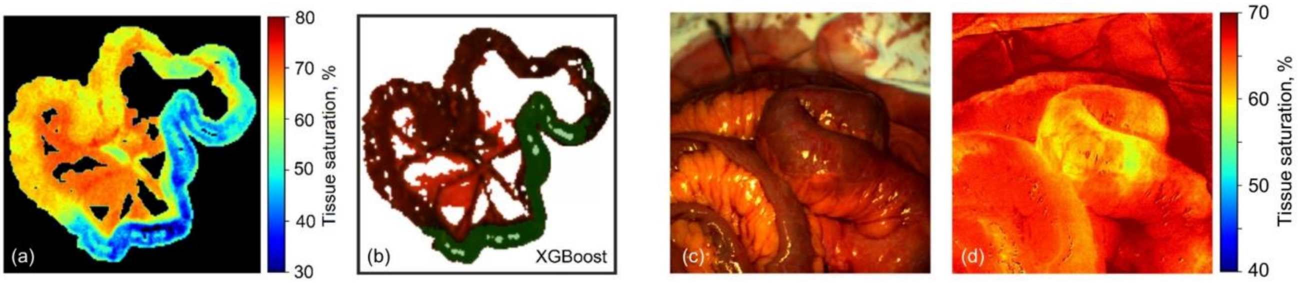

Figure 1: *(a) Example of a two-dimensional tissue saturation map for possibly reversible ischemia of the rat intestine, and (b) corresponding classification map based on the XGBoost algorithm, (c) clinical example of intestinal obstruction, and (d) corresponding tissue saturation map.*

REFERENCES

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