MULTISPECTRAL ANALYSIS FOR INTRA-OPERATIVE CHARACTERIZATION OF BRAIN TUMOURS, MARGINS OF RESECTION, AND ELOQUENT AREAS ACTIVATION – PRELIMINARY RESULTS

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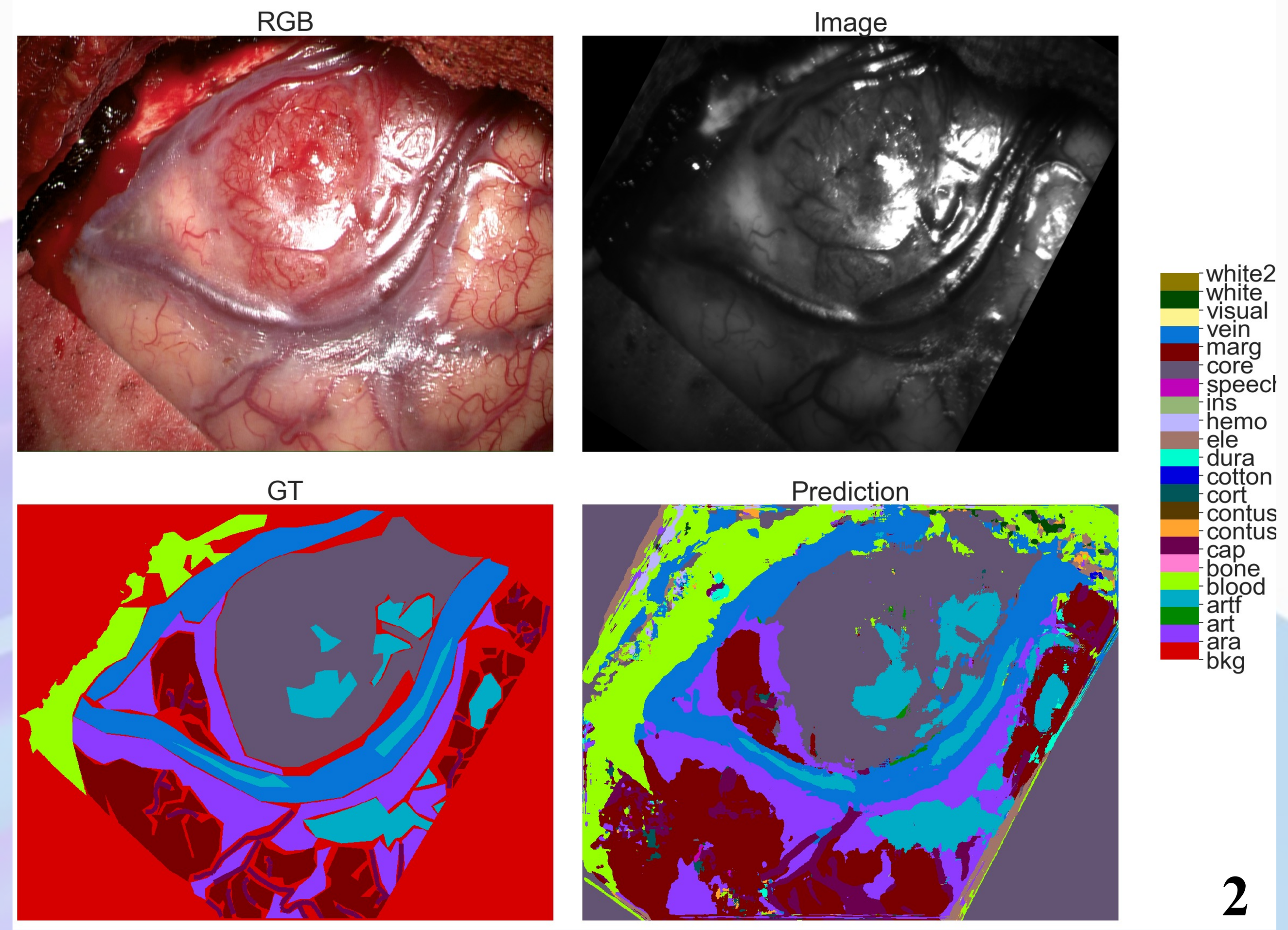
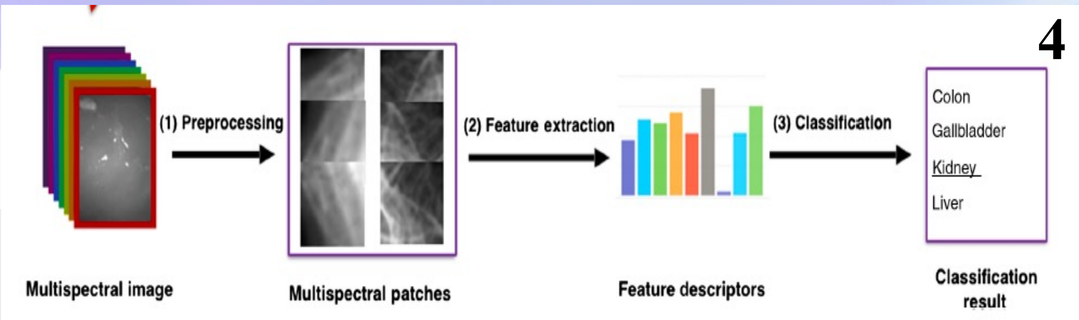
BACKGROUND - The identification of intrinsic brain tumours' boundaries and their anatomical relationship with eloquent connectomes is one of the main challenges in neurosurgery. Several new intra-operative spectroscopic technologies have been recently investigated for this purpose. Multispectral imaging (MSI) analysis is based on analysis of reflected light, divided in specific wavelengths ranges across the electromagnetic spectrum. By doing so, it can identify wavelengths invisible to the naked eye, and make them visible by applying specific filters [1].

MATERIALS AND METHODS – *Recruitment*. We have used MSI to acquire intraoperative images during brain tumours surgeries. The MSI camera has been adapted to be connected to the standard intra-operative microscope (**pic 1**) and acquire a stack of images of different spectra to be analysed on a separate time (**pic 2**). The focus of the images acquisition includes tumour structure, its margins, and eloquent connectomes during awake surgery or neurostimulation to analyse the possibility of different perfusion signal during activation. Images taken from the microscope were segmented using an in-house built software. Two different surgeons (GA and NP) were responsible of identifying and segmenting the different structures. Segmentation was cross-checked using pre-operative MRI scan to confirm presence of tumour, tumour margins and normal cortex. In order to identify and segment eloquent areas, intra-operative neurophysiology was used as a ground truth for segmentation. *Registration.* The number of the images taken under the same wavelength for averaging purpose varied from one to eight. To obtain one image for one wavelength, an image was chosen from the repeated pictures as the target.

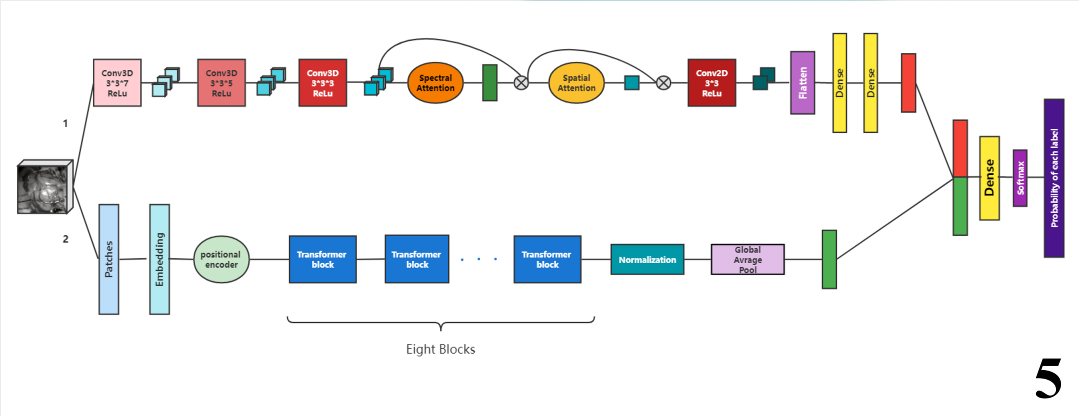

1



2



4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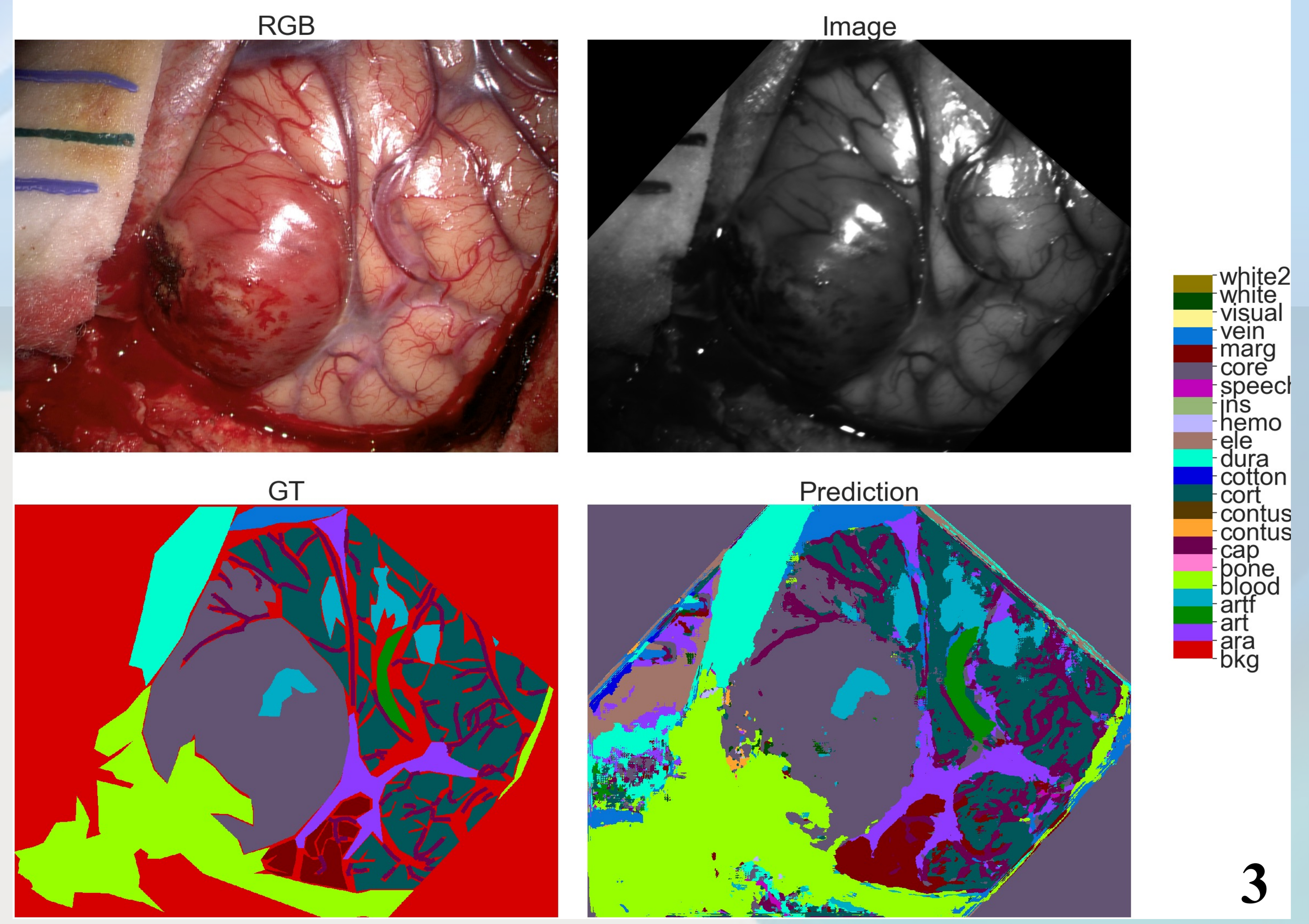

3

Pictures

1: intra-operative use of the camera device, integrated with the microscope.

2: images from case number 16 and **3:** from case number 17 showing microscope image (top left), MSI acquisition (top right), image as segmented by the authors (bottom left) and prediction (bottom right). Both cases showing excellent prediction of tumour core, vessels and tumour margins. We have labelled as "margins" all areas where a peri-lesional edema was seen on the MRI scan. **4:** process streamline, courtesy of [2]. **5:** Model structure - is a parallel structure. Line 1 is a combination of 3d and 2d convolutional neural network. Line 2 is a transformer network.

All the other images were registered to the target via Scale-Invariant Feature Transform (SIFT), and the average of these registered images was calculated as the representation of this wavelength. After selecting the representatives for each wavelength, all the images are ready to be registered to their corresponding white light microscope images recorded with the Zeiss camera. The colour microscope images were split into Red, Green and Blue channels, and the multi-spectral images were split into red, green and blue groups via their wavelength (460--530 of nm for blue; 540-610 of nm for green; 620-720 of nm for red). The method used to solve this problem was as follows: 1) reconstructing an image from each group; 2) registering the reconstructed image to its corresponding split channel; 3) Registering the images in each group to their corresponding registered reconstructed images via SIFT (**pic 5**).

RESULTS. Thirty patients have been enrolled in the current study at the time of this submission, and we have analysed data for 23 of them. Patients' features are summarized in **Table 1**. The range of wavelengths used for all cases ranged from 440 nm to 720 nm. On the present dataset, MS has shown high accuracy rate in identifying basic anatomical structures such as cortex, white matter, veins, arteries, and dura. We have also observed high sensitivity and specificity in identifying the tumour core and margins from the surrounding structures (**pic 2 and 3**).

TABLE 1	
Age	58 (±14)
Gender	13 M, 10 F
Histology	18 gliomas
	4 meningiomas
	1 metastasis
Adverse events	1 CSF leak
	1 intra-operative hematoma
	1 post-op infection
	1 post-op stroke, asymptomatic
Adverse reactions	None

CONCLUSIONS. Our preliminary results show that MSI is a potential additional technology to visually show tumour core, margins, and different degree of perfusions on the tissues analysed during tumour surgery. In two patients with tumours in eloquent areas we were able to detect changes in the reflectance spectra during activation. However, more data are needed to confirm this finding.

REFERENCES
1. Shapey J, Xie Y, Nabavi E, Bradford R, Saeed SR, Ourselin S, Vercauteren T. Intraoperative multispectral and hyperspectral label-free imaging: A systematic review of in vivo clinical studies. J Biophotonics. 2019 Sep;12(9):e201800455.
2. Zhang Y, Wirkert SJ, Iszatt J, Kenngott H, Wagner M, Mayer B, Stock C, Clancy NT, Elson DS, Maier-Hein L. Tissue classification for laparoscopic image understanding based on multispectral texture analysis. J Med Imaging (Bellingham). 2017 Jan;4(1):015001.