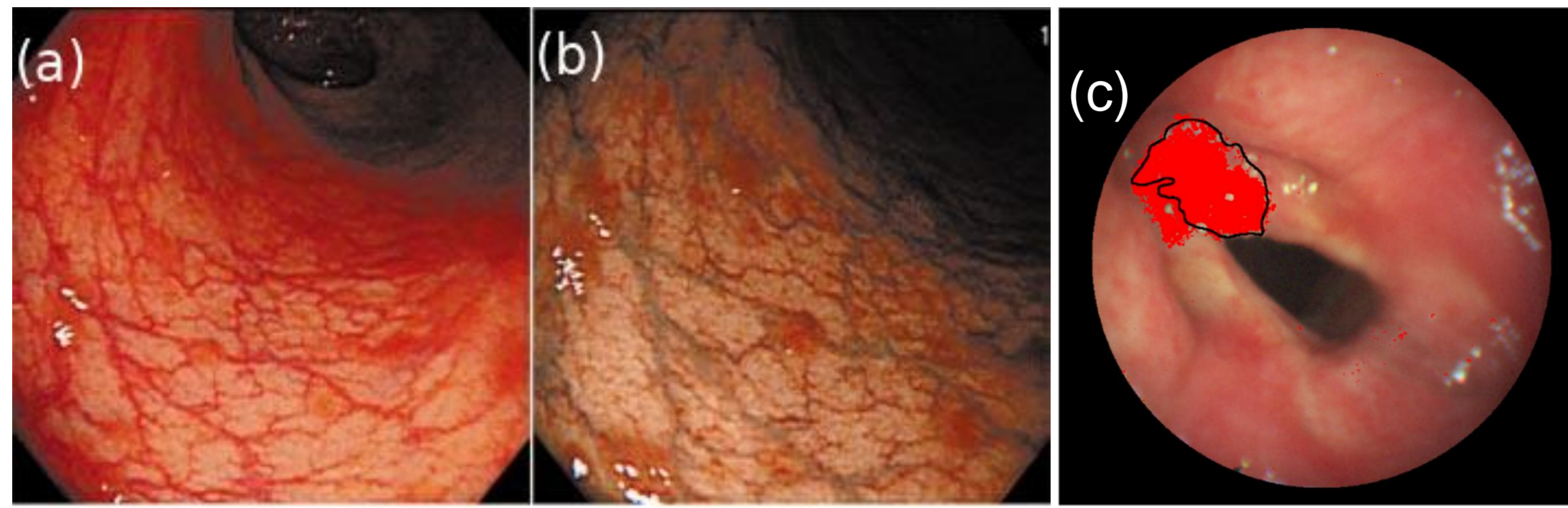


Multispectral Endoscopic Setup for Real Time Pathology Detection

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Introduction



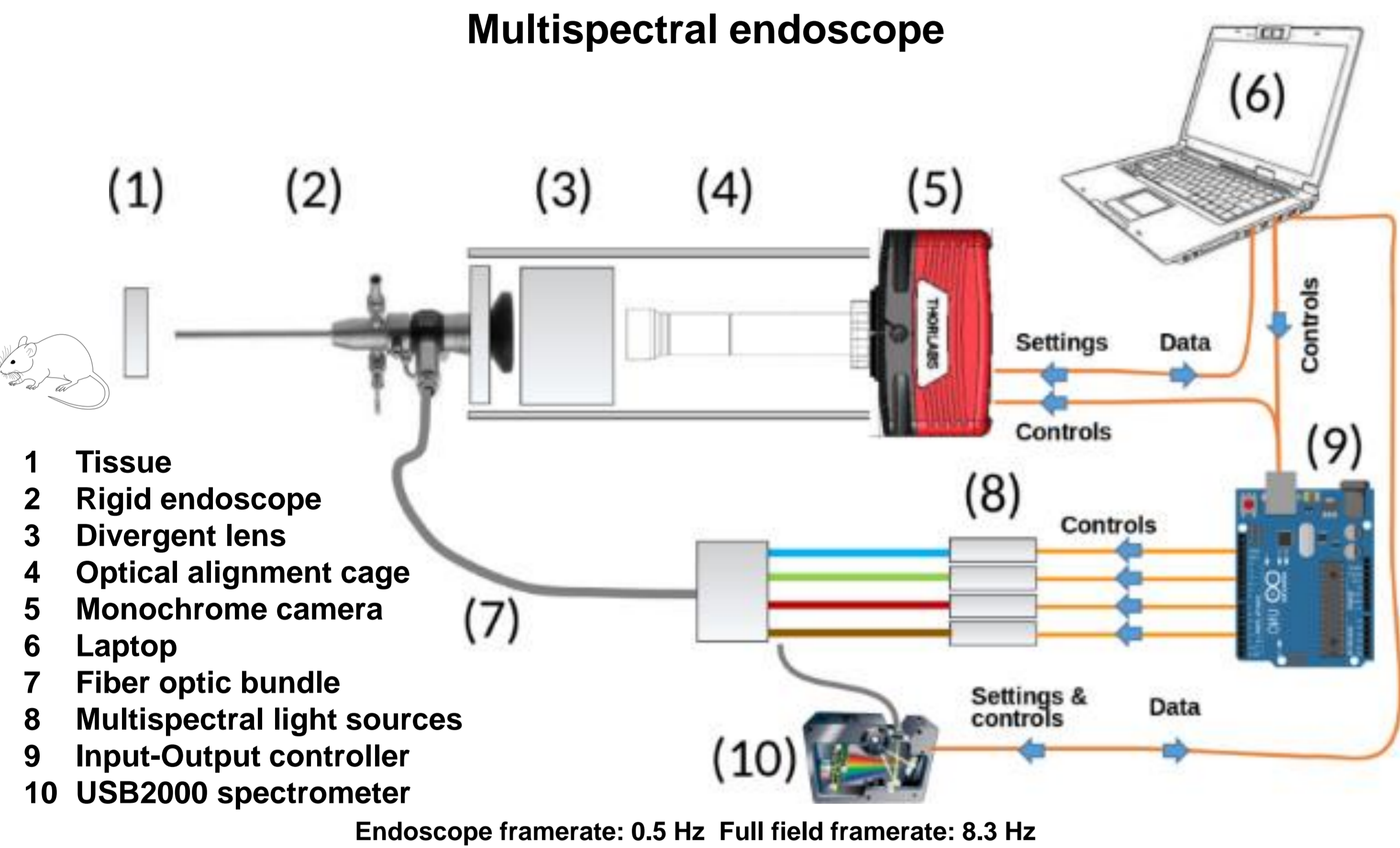
	Tissue detection (a) (b)	Tissue characterization (c)
Camera	RGB (distal end)	HSI (proximal end) [2-4]
Acquisition time	≈ 33ms	> 1s
Field of view	Extended	Reduced
Spectral resolution	Low	High
Lesion damage identification	Visual appreciation of the practitioner	Spectral analysis

(a) White light endoscopy. (b) NBI endoscopy [1].
(c) Hyperspectral (HIS) endoscopy (Tumor identification) [2]

There is a need to provide quantitative or semi-quantitative indicators to the practitioner to assist them during a tissue detection examination using flexible tube endoscopes

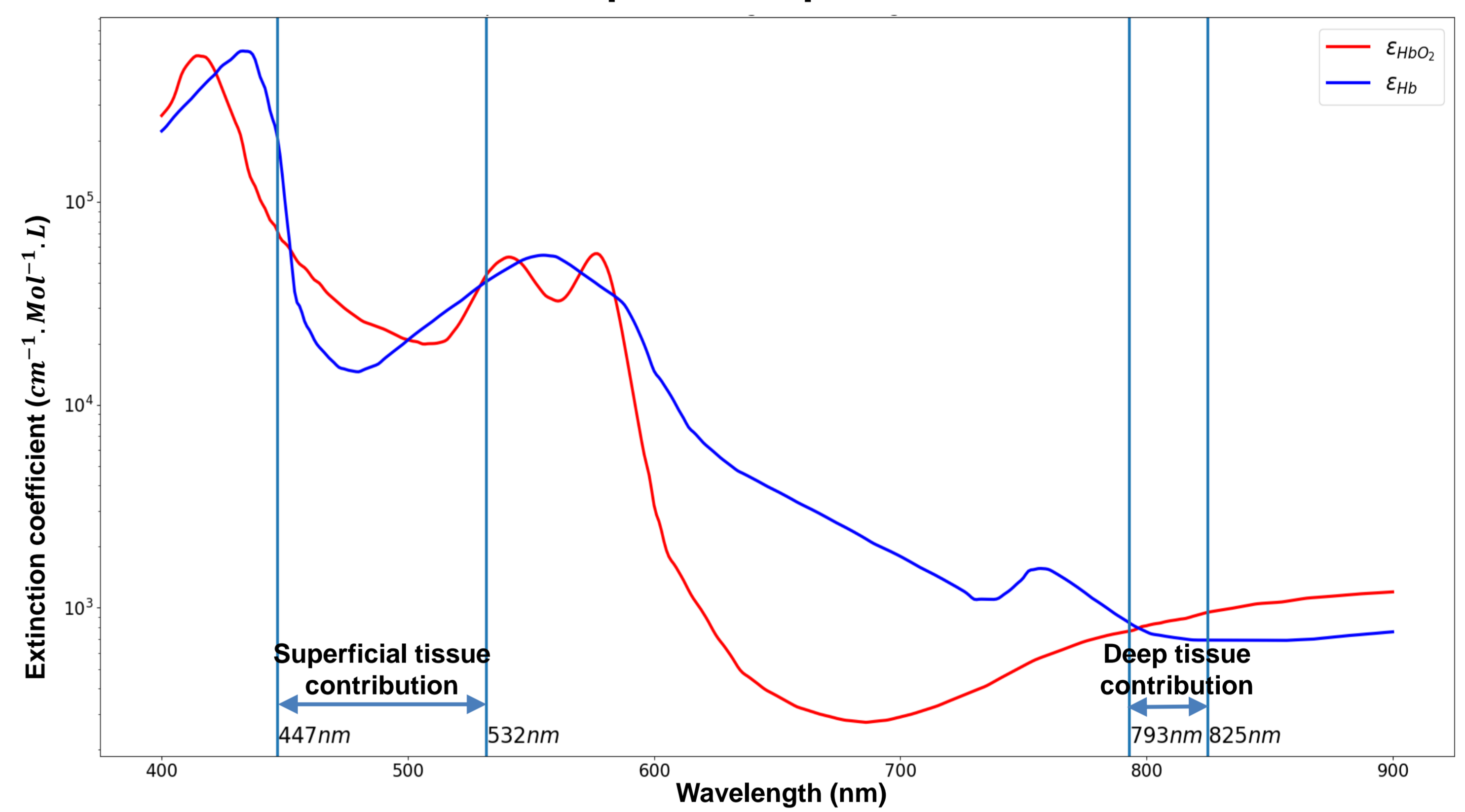
Methods

Multispectral endoscope



Endoscope framerate: 0.5 Hz Full field framerate: 8.3 Hz

Per-endoscopic multispectral illumination



Semi-quantitative indicators

Superficial tissue

$$x_{mes} = \frac{I'_{447nm}}{I'_{532nm}}$$

Superficial tissue representation

$$I_S = \begin{cases} H & : x_{mes} \\ L & : I'_{447nm} \\ S & : I'_{532nm} \end{cases}$$

Deep tissue

$$y_{mes} = \frac{I'_{825nm}}{I'_{793nm}}$$

Deep tissue representation

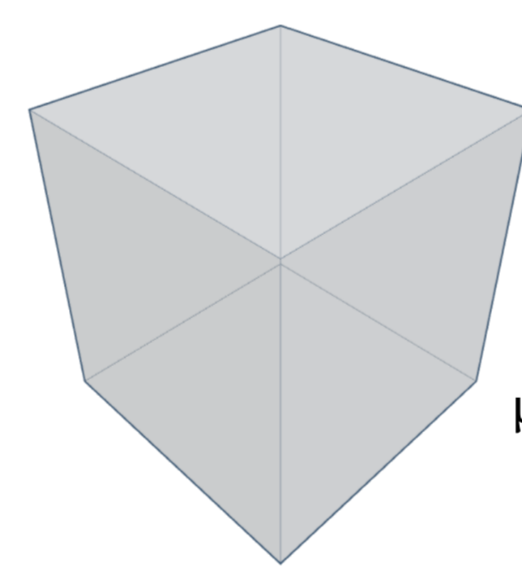
$$I_P = \begin{cases} H & : y_{mes} \\ L & : I'_{825nm} \\ S & : I'_{793nm} \end{cases}$$

Blood volume

$$z_{mes} = \frac{I'_{532nm}}{I'_{793nm}}$$

Simulation of the semi-quantitative indicators [5]

Homogeneous volume of tissue



Range of variation of simulated optical properties

$$\mu_a(\lambda) \begin{cases} 10 \leq C_{HbT} \leq 4000 \mu\text{Mol/L} \\ 0 \leq \text{SatO}_2 \leq 100\% \end{cases}$$

$$\mu_s'(\lambda) = \sigma \cdot \frac{\lambda}{500}^{-\beta} \begin{cases} \sigma = 22 \text{cm}^{-1} \\ 0.1 \leq \beta \leq 1.2 \end{cases}$$

Physiological parameters estimation

C_{HbT} estimation

$$C_{HbT}^{\sim} = \min_{C_{HbT}} |z_{simu}(C_{HbT}) - z_{mes}|$$

«Superficial» SatO₂ Estimation

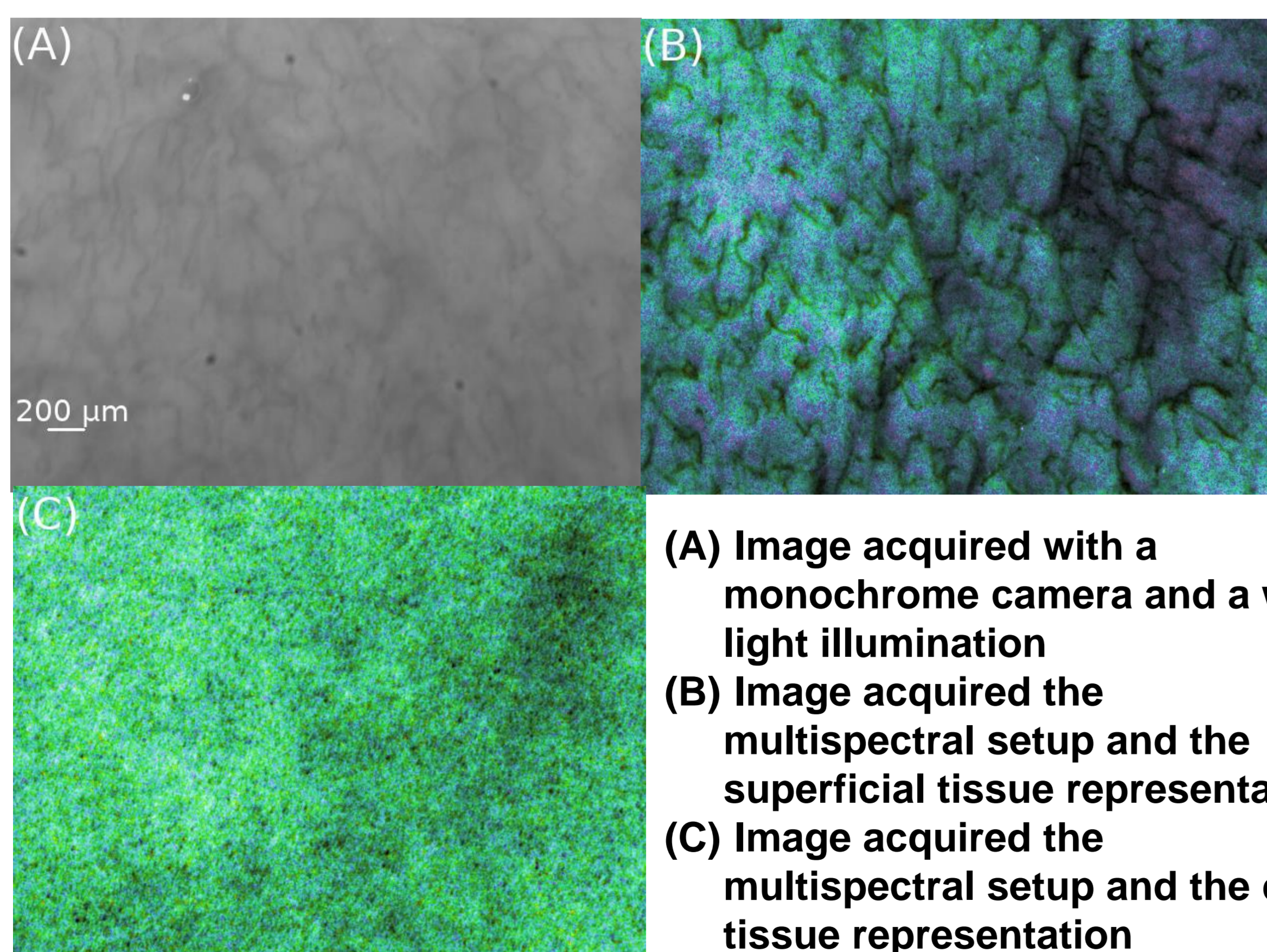
$$\text{SatO}_2^S = \min_{\text{SatO}_2} |x_{simu}(C_{HbT}^{\sim}, \text{SatO}_2) - x_{mes}|$$

«Depth» SatO₂ Estimation

$$\text{SatO}_2^P = \min_{\text{SatO}_2} |y_{simu}(C_{HbT}^{\sim}, \text{SatO}_2) - y_{mes}|$$

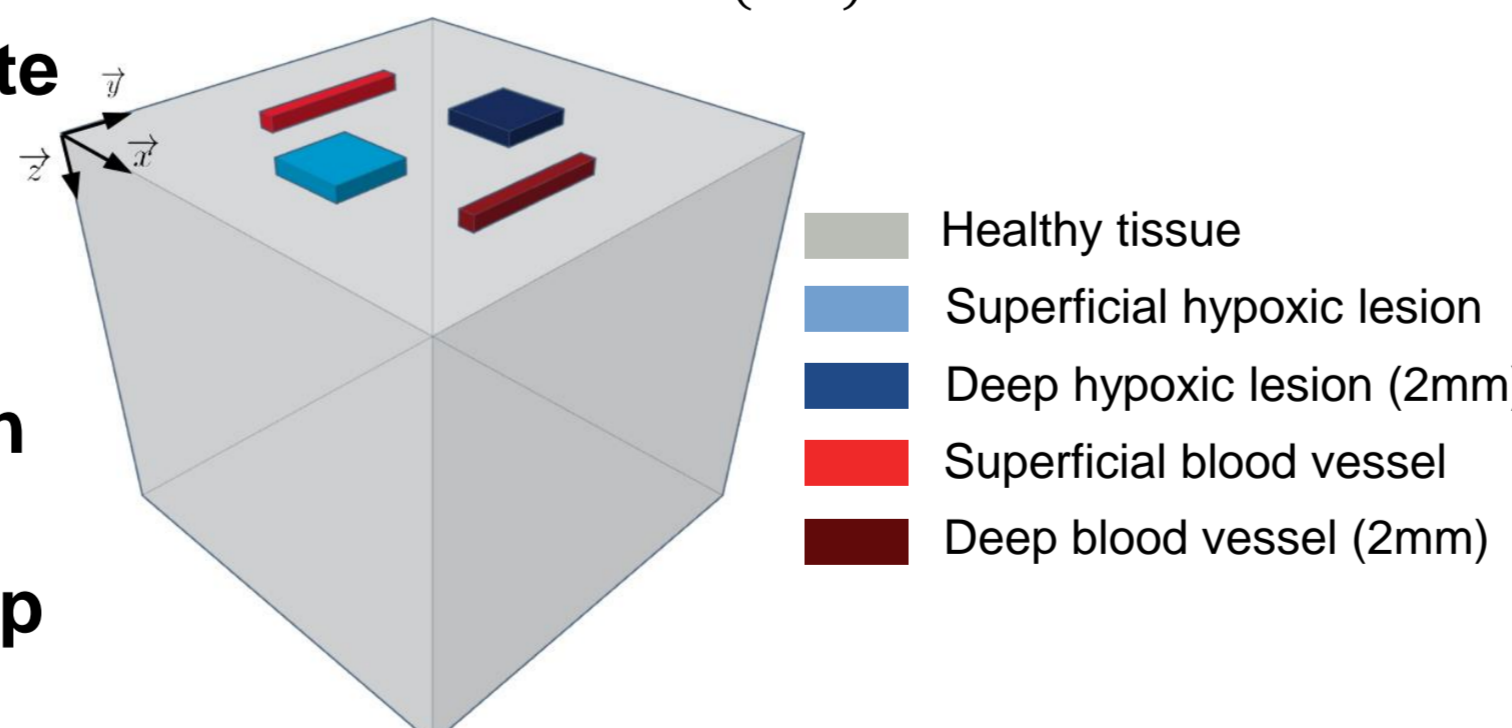
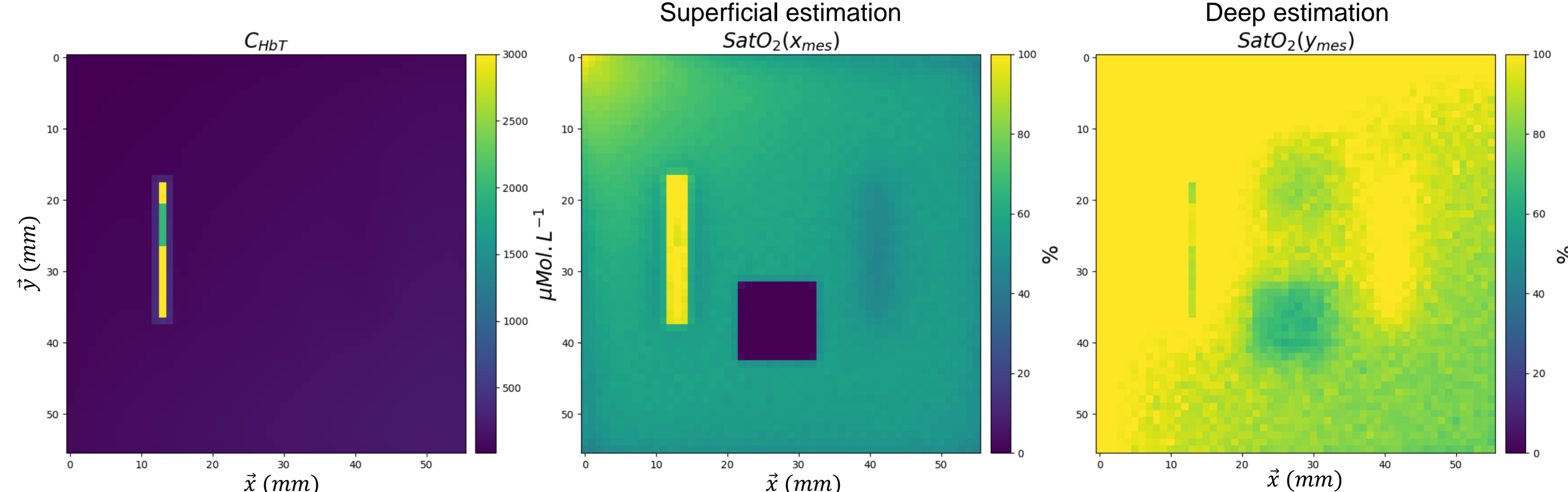
Results

In-vivo images (lip tissue) acquired without the rigid endoscope and the divergent lens



(A) Image acquired with a monochrome camera and a white light illumination
(B) Image acquired with the multispectral setup and the superficial tissue representation
(C) Image acquired with the multispectral setup and the deep tissue representation

Physiological parameters estimation using a numeric phantom



		Blood vessel		Hypoxic lesion		Healthy tissue
		Surf.	Depth	Surf.	Depth	
C _{HbT} (μMol/L)	Reference	2500	2500	87.1	87.1	87.1
	Estimation	1064	110	114	74	101
SatO ₂ (%)	Reference	95	95	8	8	74.6
	Surface estimation	98	47	0	60	58
	Depth estimation	97	98	71	90	93

Discussion and Conclusion

Proof of concept for pathological tissue detection in flexible tube endoscopy

- Multispectral endoscope
- Real time processing
- Semi-quantitative representation for the identification of superficial and deep tissue lesions
- Possible discrimination between healthy tissue, surface blood vessel and hypoxic lesion

Perspectives

- Improve light injection into the endoscope
- Improve the estimation model
- Evaluate the estimation model with an optical phantom



[1] K. Gono et al. (2004) J. Biomed. Opt. 9(3) 568-577
[2] R. Kumashiro et al. (2016) Anticancer research 36:3925-32
[3] R. T. Kester et al. (2011) J. Biomed. Opt. 16(5) 056005
[4] B. Regeling et al. (2016) Sensors 16, 1288
[5] Q. Fang et al. (2009) Opt. Express, 17(22)