Jin Pok Kim Lecture

Image-guided surgery applied to the digestive system

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13th International Gastric Cancer Congress (IGCC) 2019

May 9th 2019, Prague

The evolution of imaging-guided surgery

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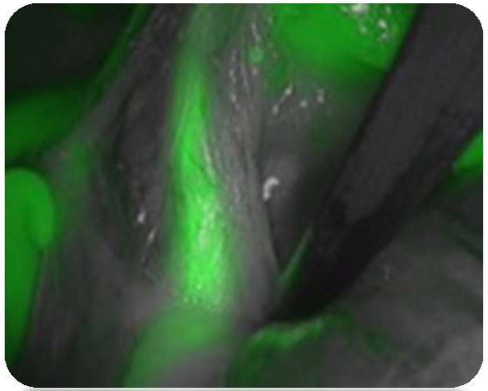
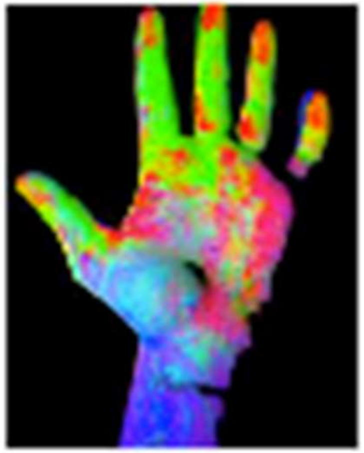
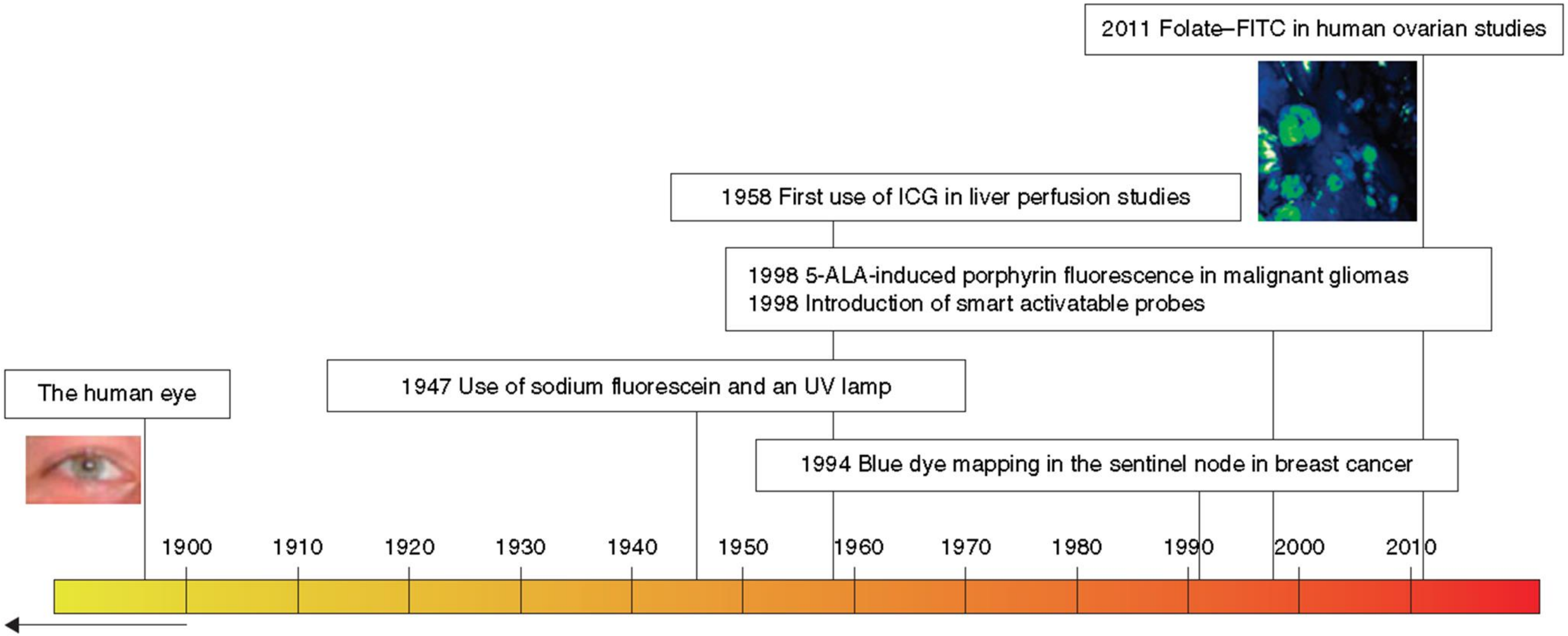


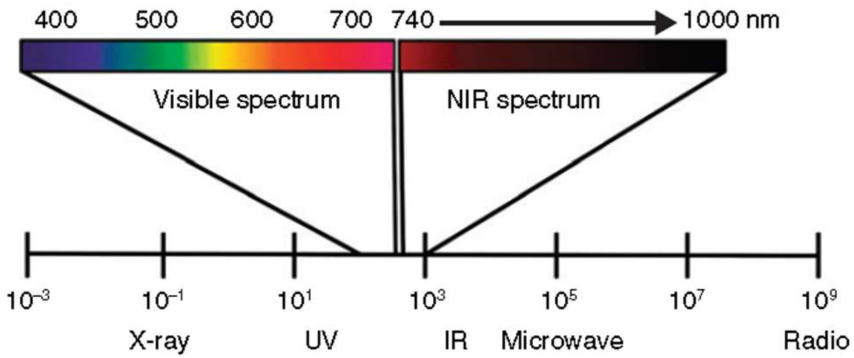



Development of clinical optical imaging

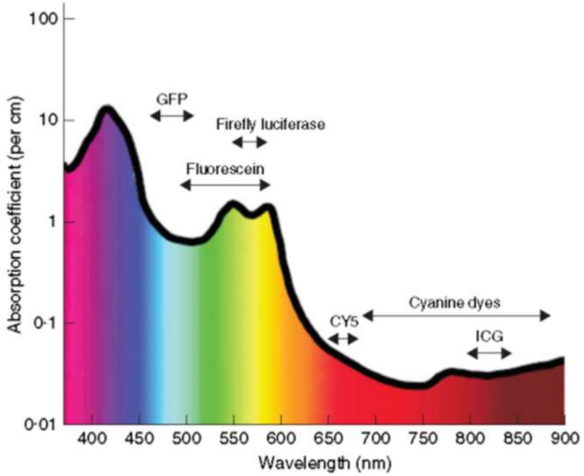


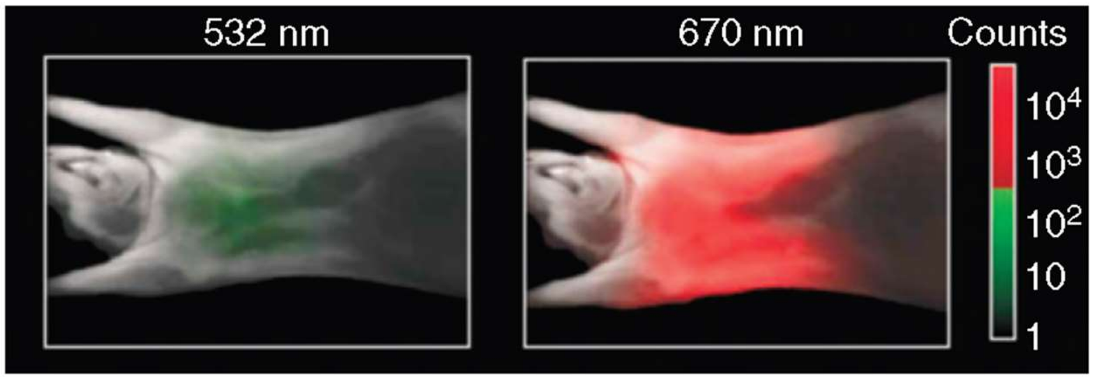
de Boer E, et al. *BJS 2015*

Principles of intraoperative optical imaging



- Optical imaging related to the electromagnetic spectrum
- NIR is not visible to the human eye and can be detected by sensitive charge-coupled device cameras only





de Boer E, et al. *BJS 2015*

Hallmarks of cancer and their targets for optical imaging

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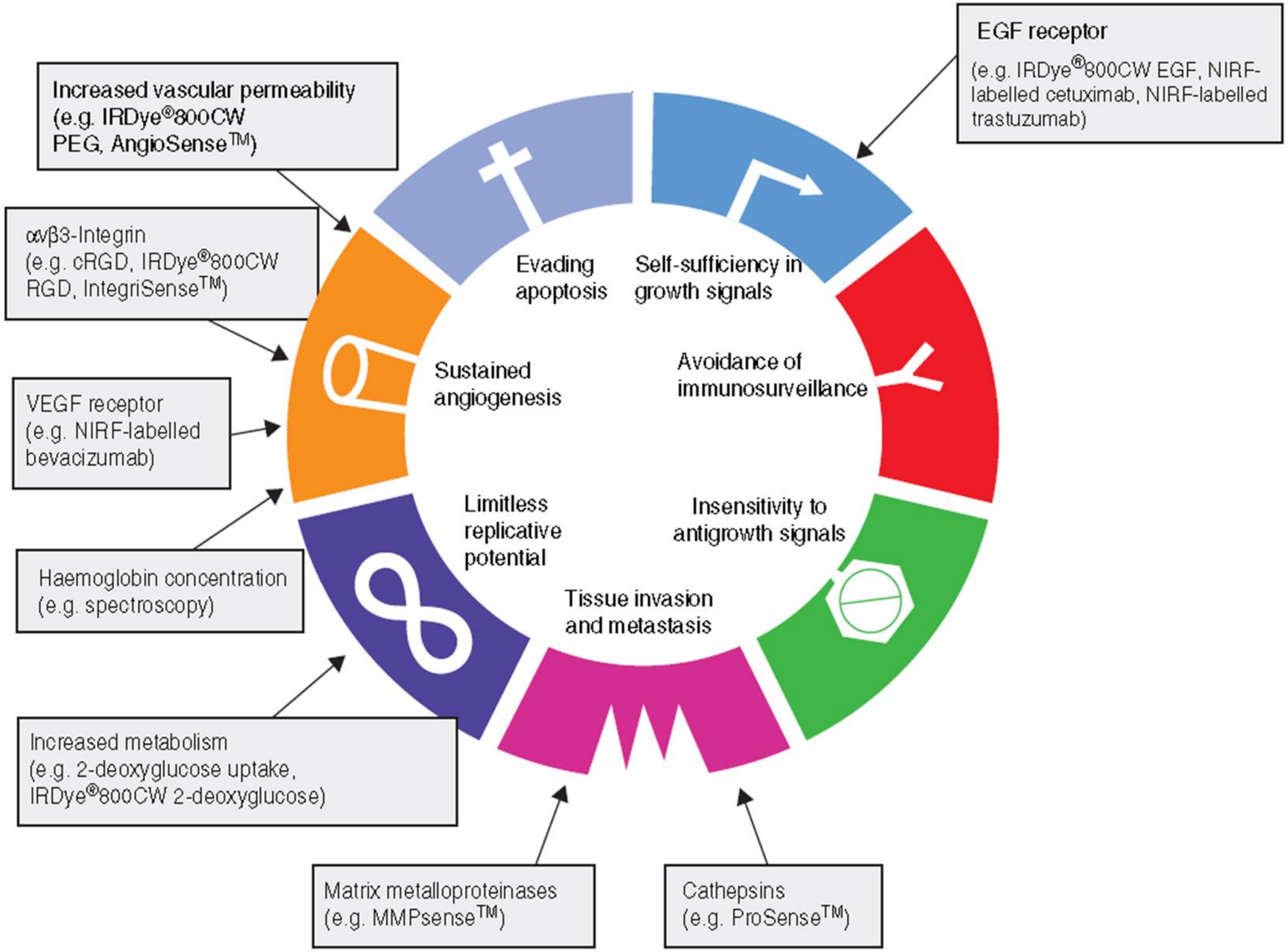

de Boer E, et al. *BJS 2015*

Biomarker selection tool and TArget Selection Criteria (TASC) and scoring system

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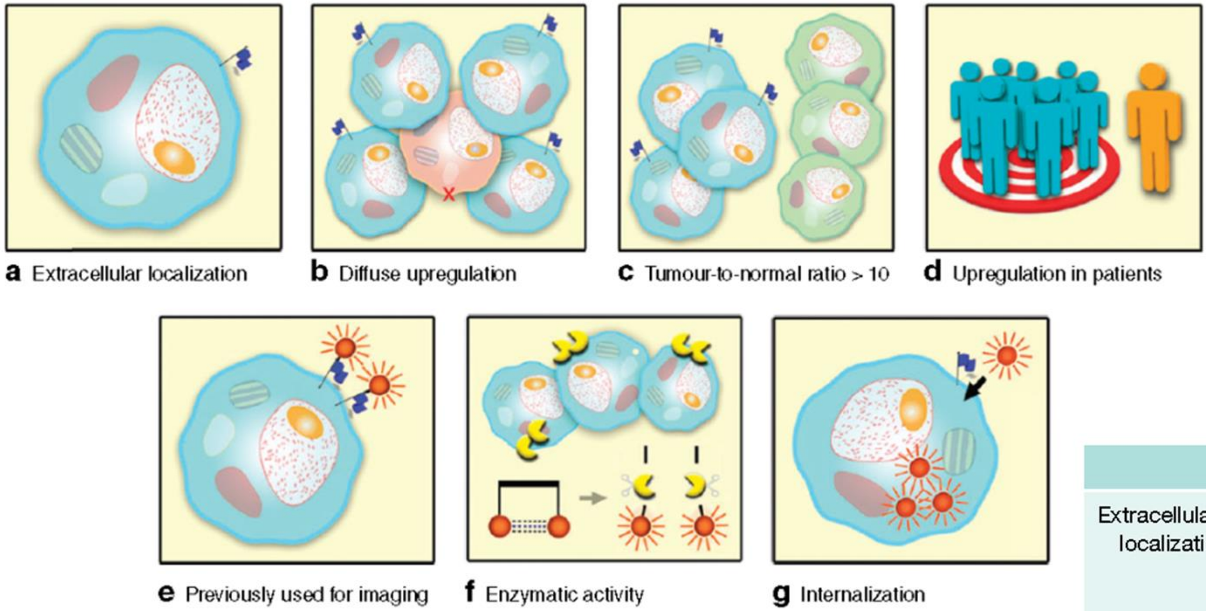
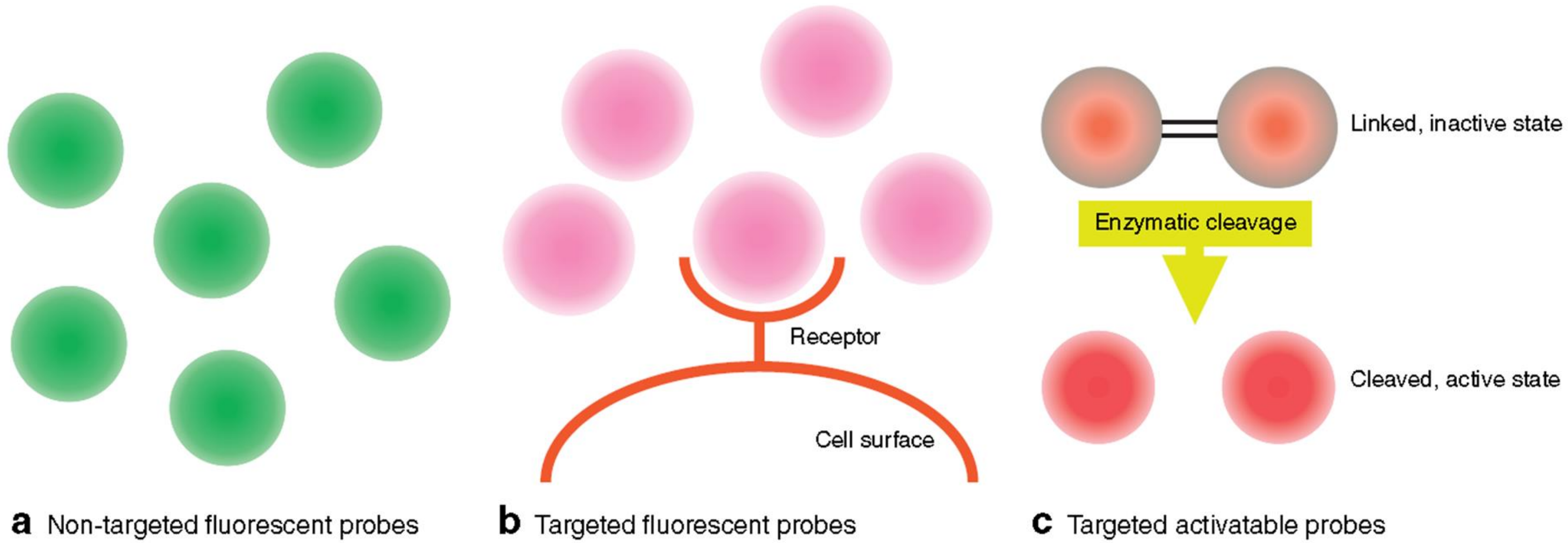


		Score
Extracellular protein localization	Bound to cell surface (receptor)	5
	In close proximity to tumour cell	3
Diffuse upregulation through tumour tissue		4
Tumour-to-normal ratio >10		3
Percentage upregulation in patients	> 90%	6
	70–90%	5
	50–69%	3
	10–49%	0
Previously used *in vivo* for imaging with success		2
Enzymatic activity		1
Internalization		1

de Boer E, et al. *BJS 2015*

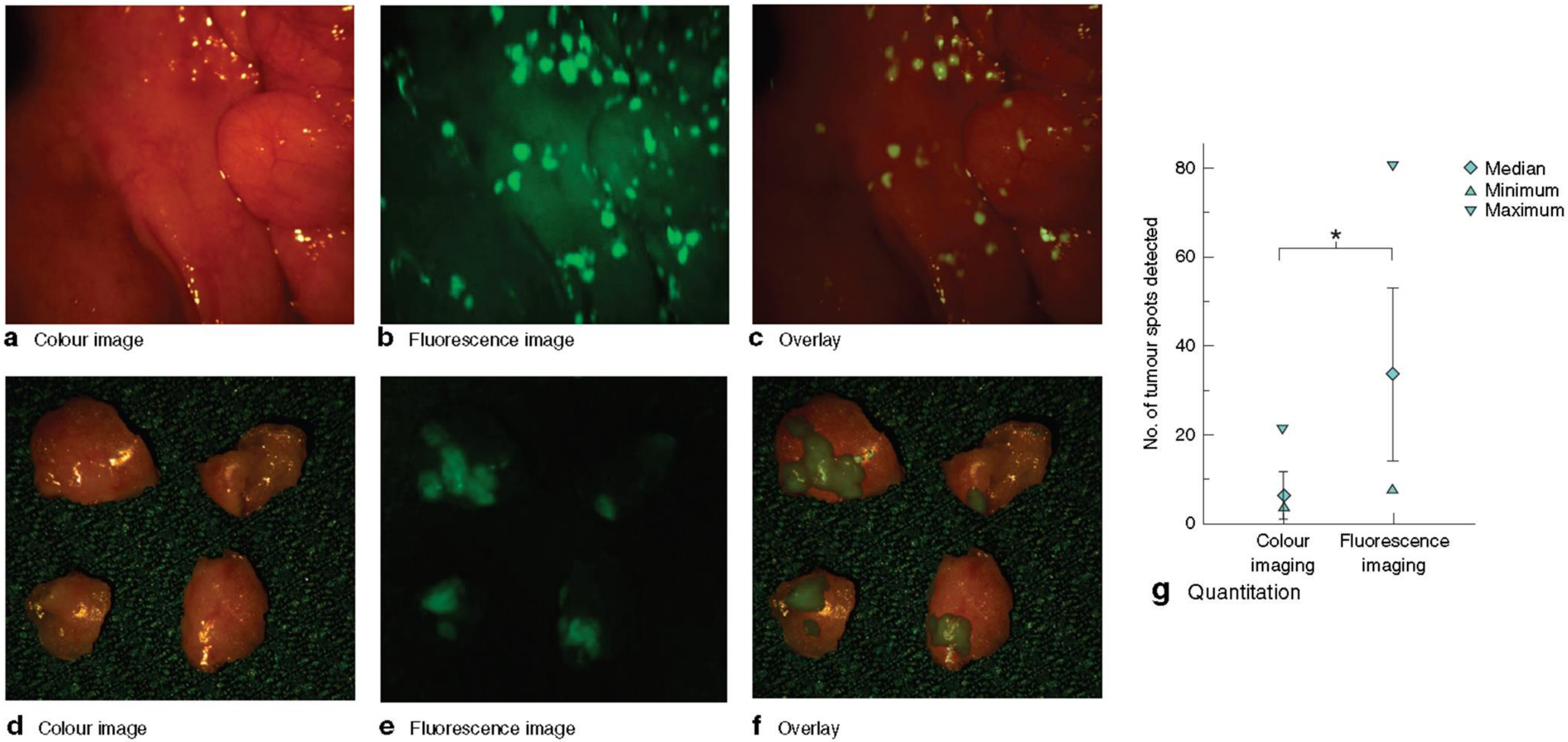
Mechanism of action of fluorescent probes



de Boer E, et al. *BJS 2015*

First human imaging of ovarian cancer, targeting folate receptor

- Systemic injection of folate-fluorescein isothiocyanate



de Boer E, et al. *BJS 2015*

Intraoperative photoimmunodetection and -therapy

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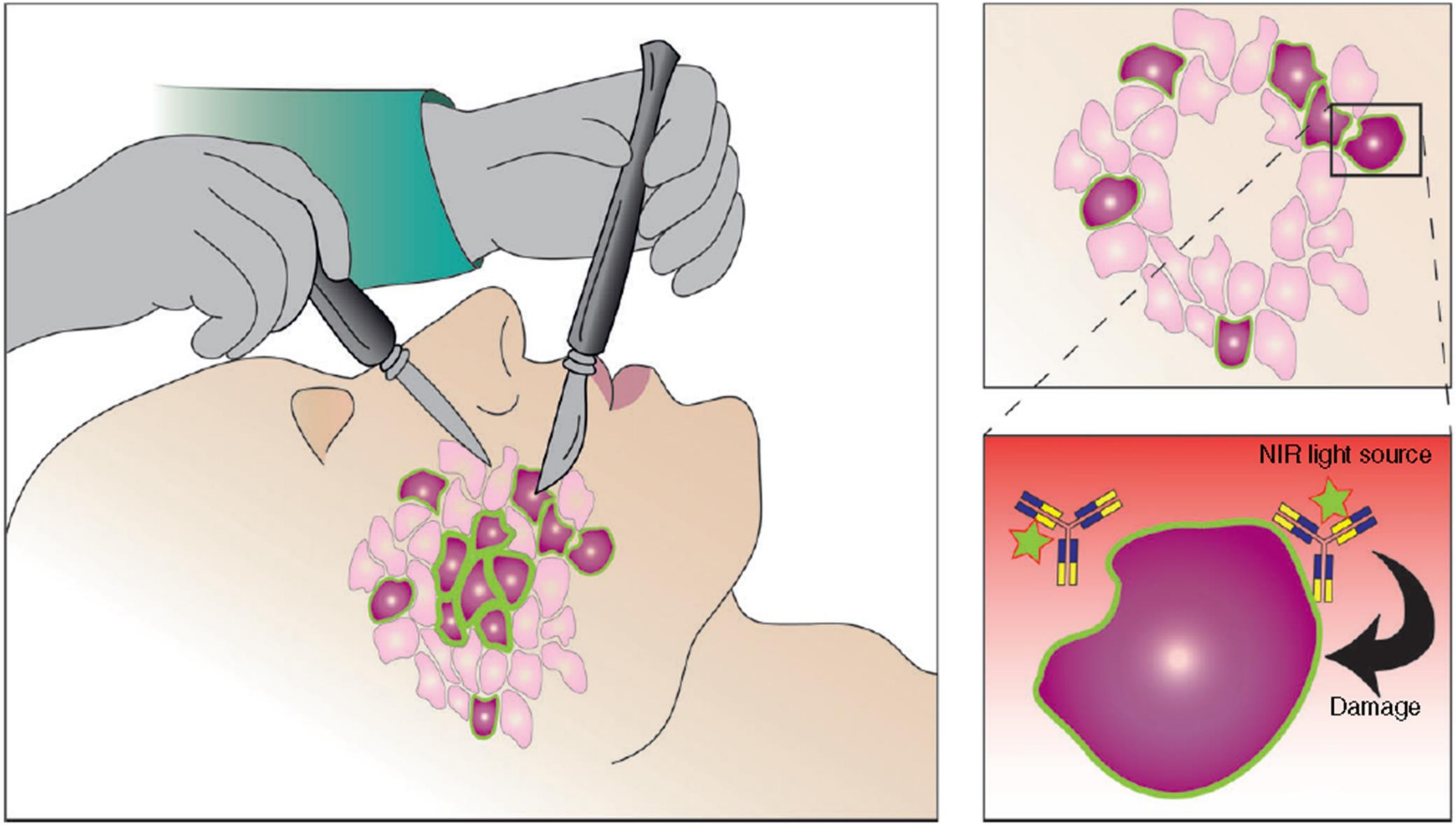
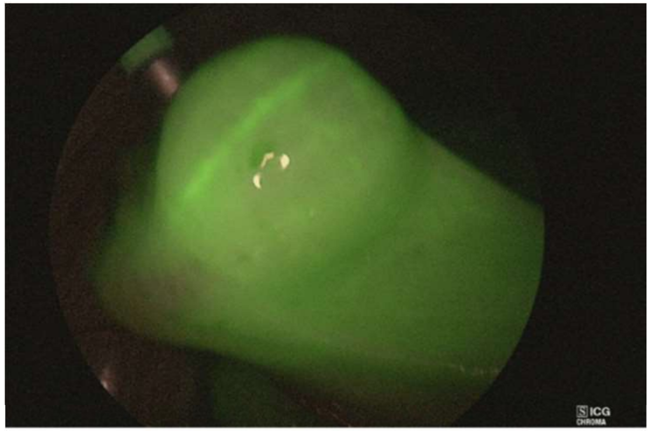


a Photoimmunodetection **b** Phototherapy

de Boer E, et al. *BJS 2015*

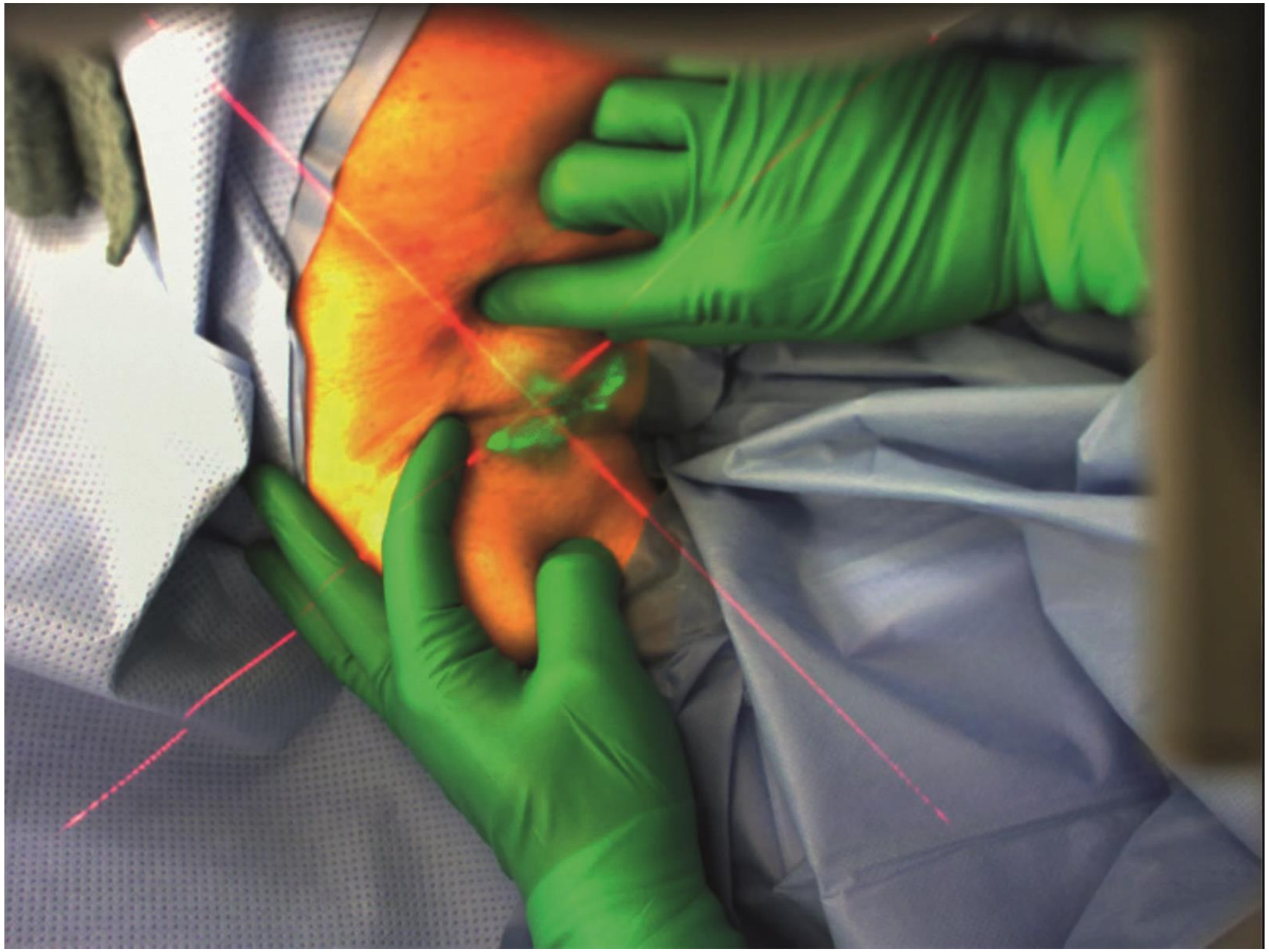
ICG = IndoCyanine Green



ICG properties

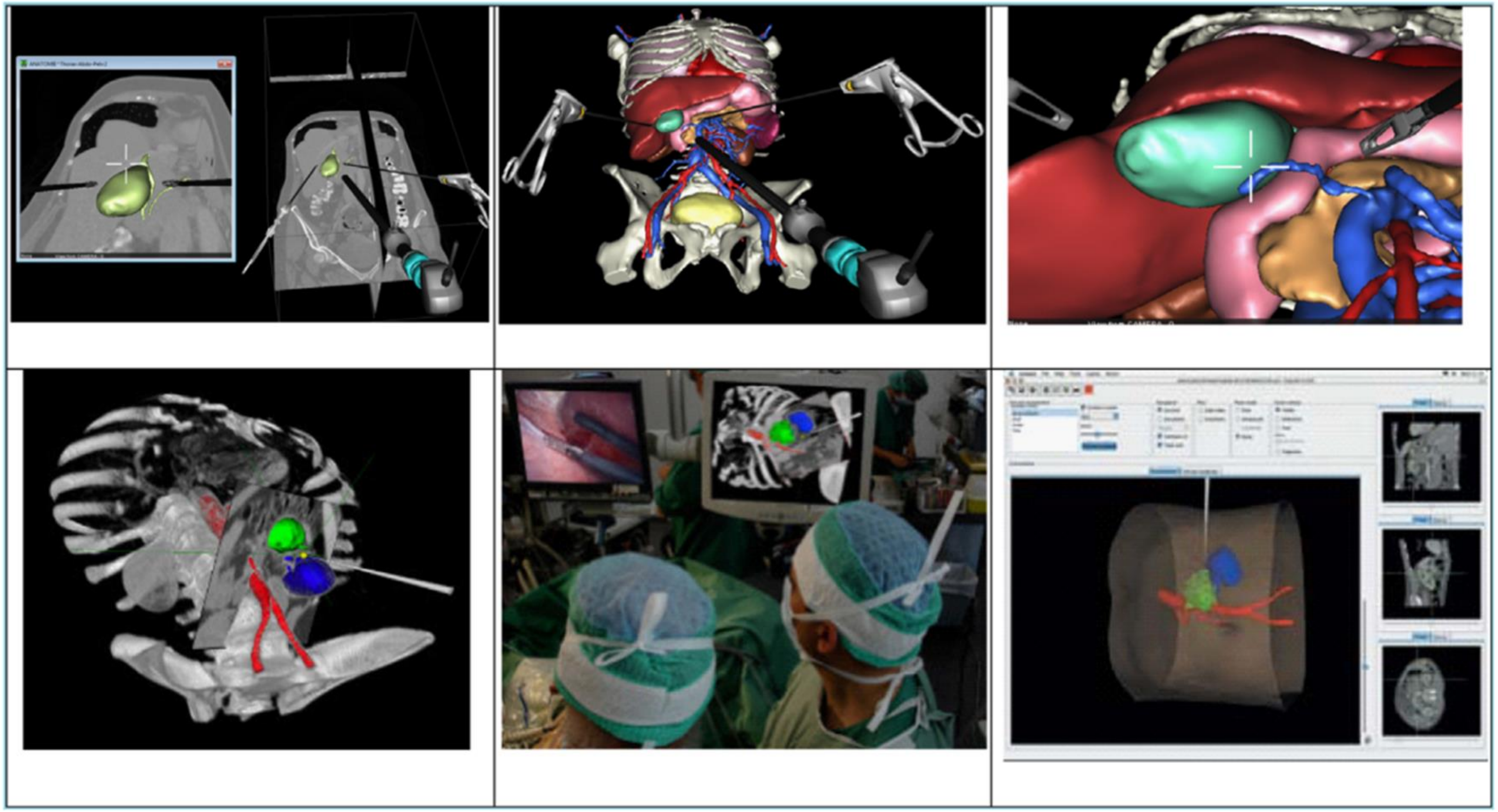
- **Protein binding** – to plasma proteins quickly, ß-Apolipoprotein B (95%)
- **Metabolism** – ICG is not metabolized
- **Elimination** – biphasic with an initial half life of 3-4 min and a second t ½ of about 60-80 min; elimination via bile (unconjugated)
- **Concentration maximum** – in bile after ½ to 2 hours

Augmented Reality (AR)



Augmented virtuality-based navigation system

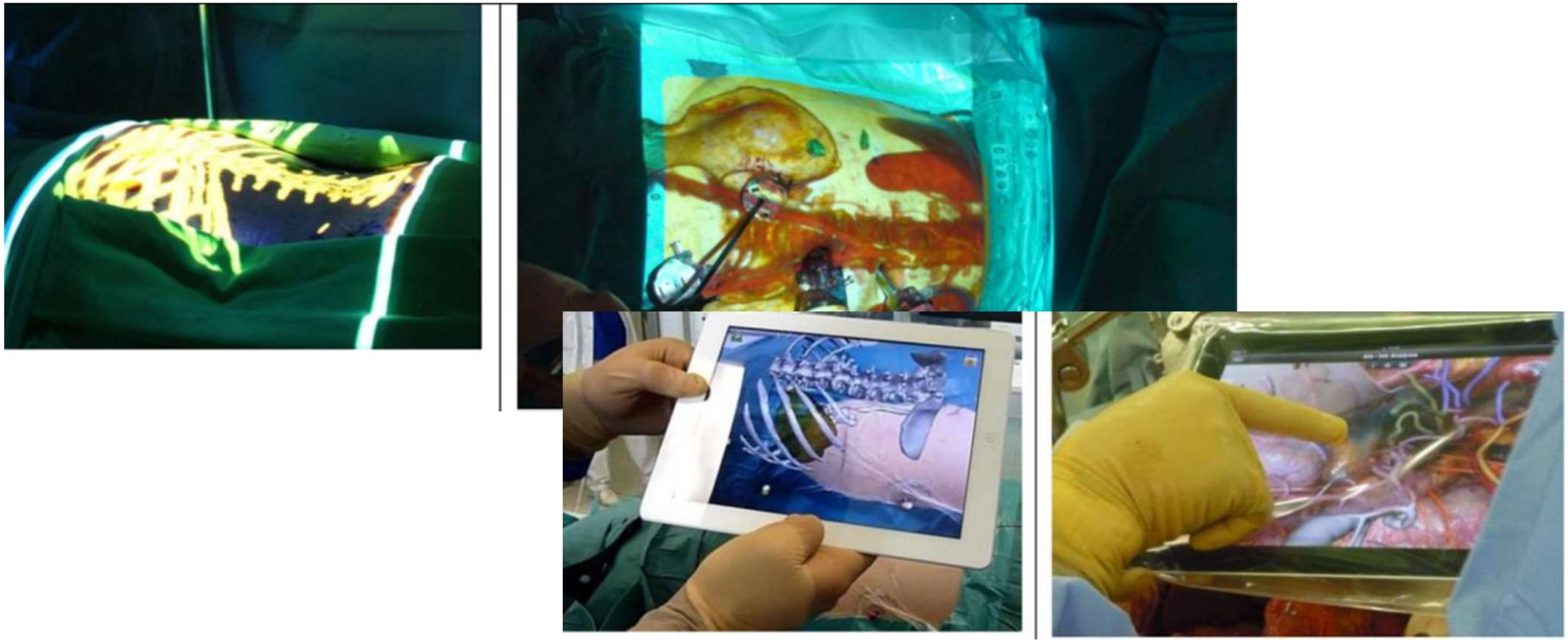
- 3D patient model using CT scan data only or 3D model associated to the instrument positions, which are updated in real time due to a tracking system



Azagury DE, et al. *Curr Probl Surg 2015*

Data superimposition

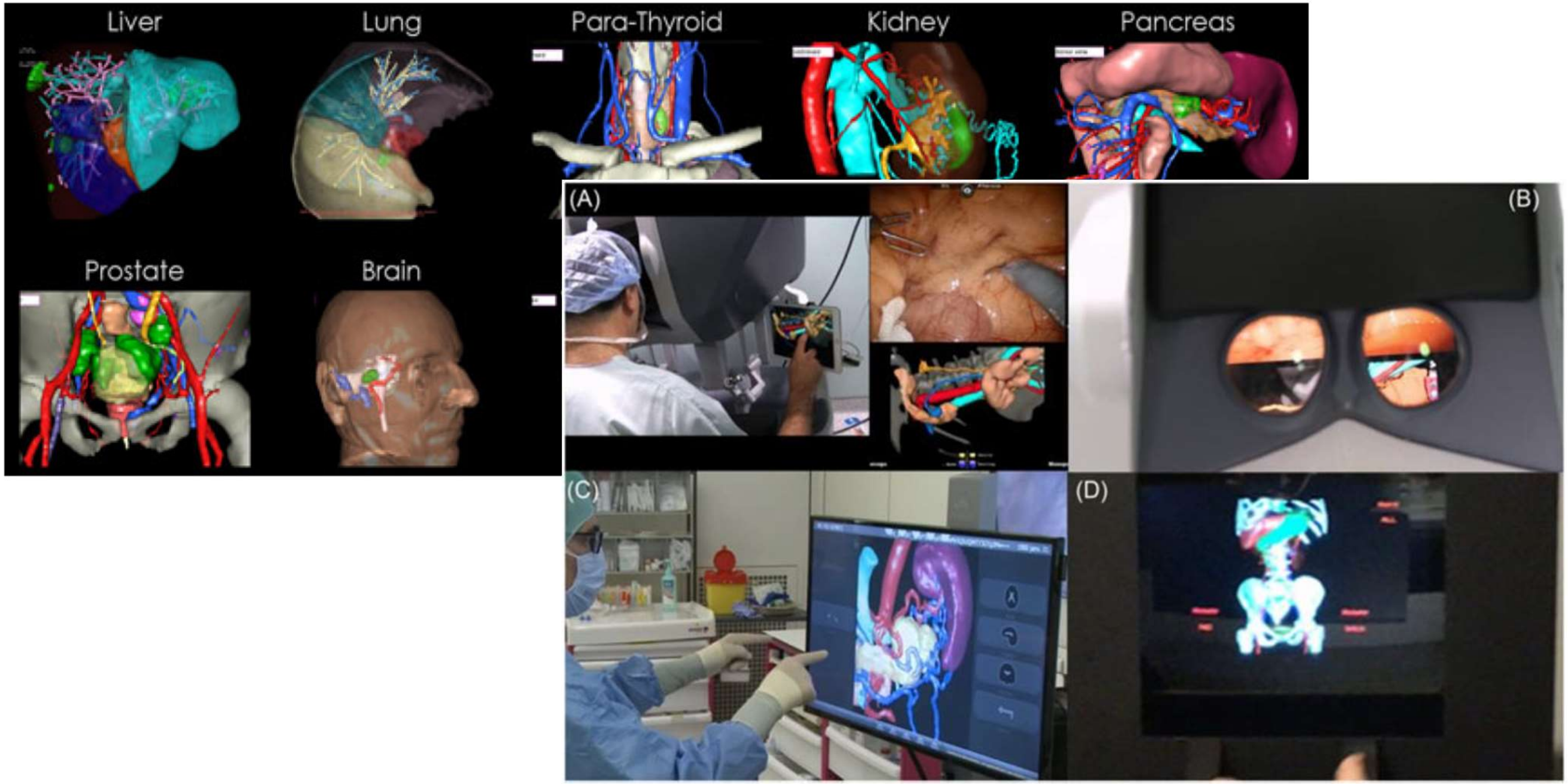
- tablet, PC: illustration of patient model directly projected on patient skin or organ surface
- overlay of preoperative patient 3D model using landmarks, which are automatically tracked in the video using image processing



Azagury DE, et al. *Curr Probl Surg 2015*

Virtual Reality 3D modeling

- examples of human body modeling using surface rendering technique & display the 3D model in the OR



Mascagni P, et al. *J Surg Oncol 2018*

Augmented Reality overlay in laparoscopic surgery

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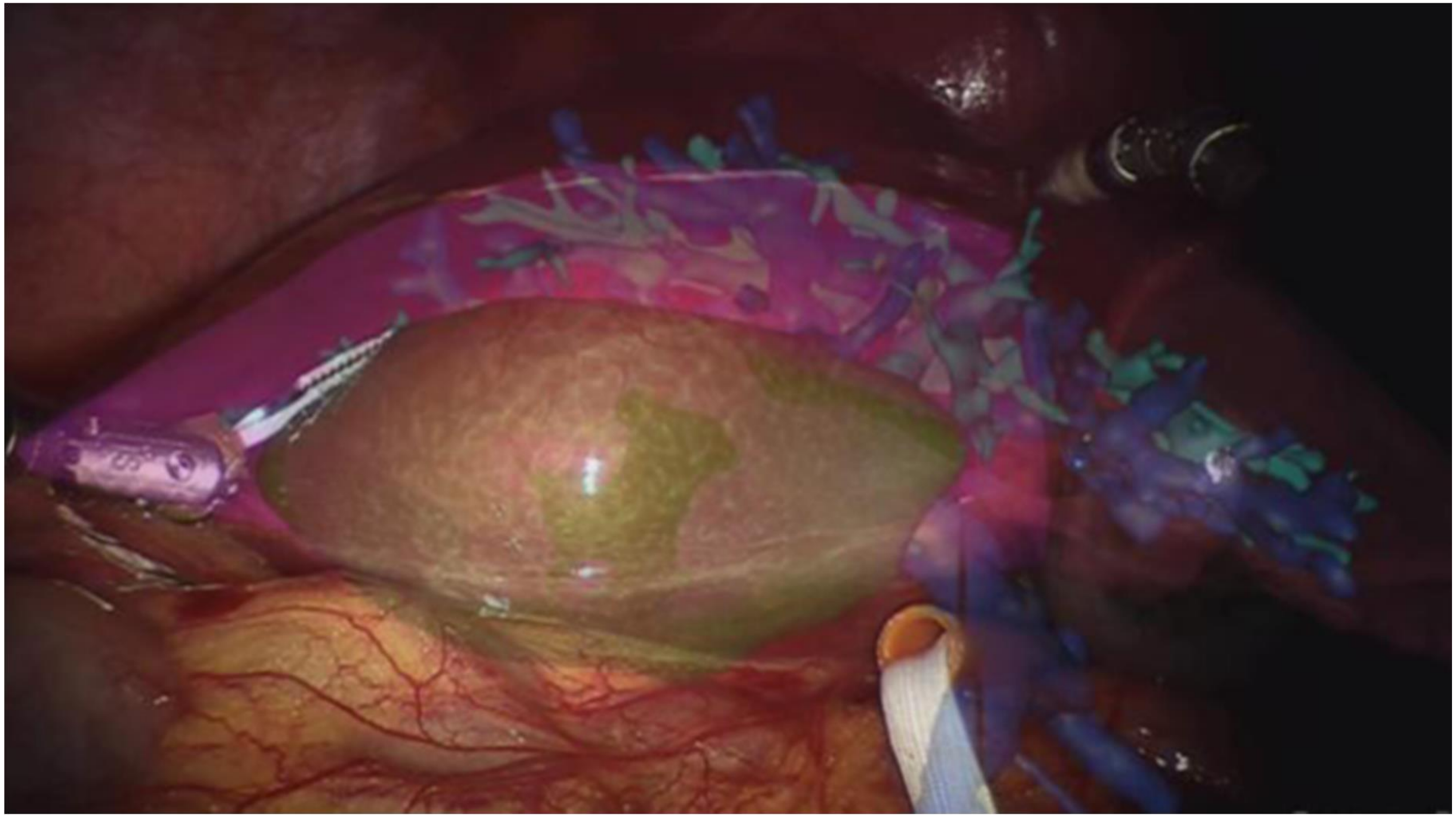
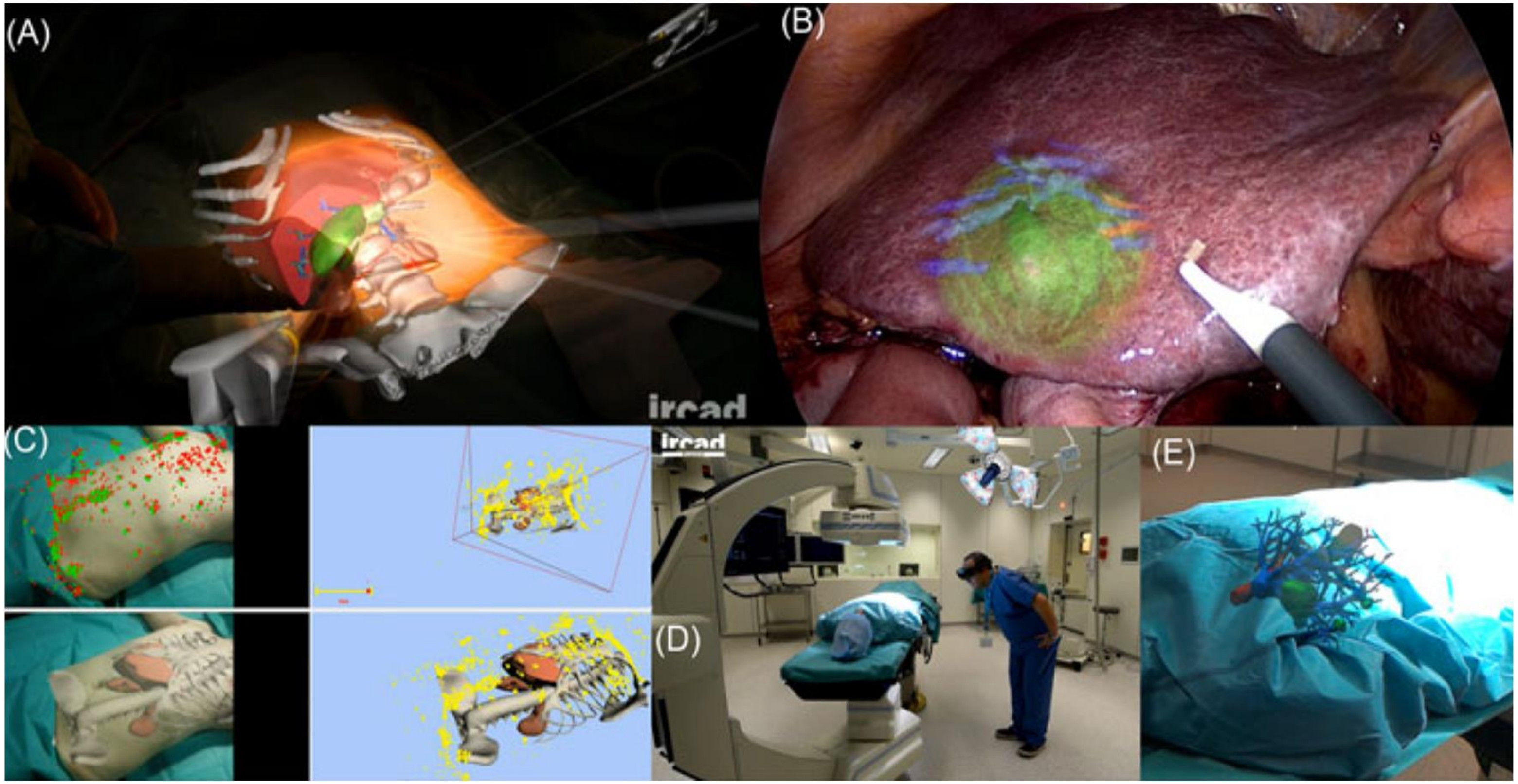
- liver tumor (green), surrounding vessels (dark and light blue) and the resection plane (pink)



Azagury DE, et al. *Curr Probl Surg 2015*

Modalities for display of Augmented Reality

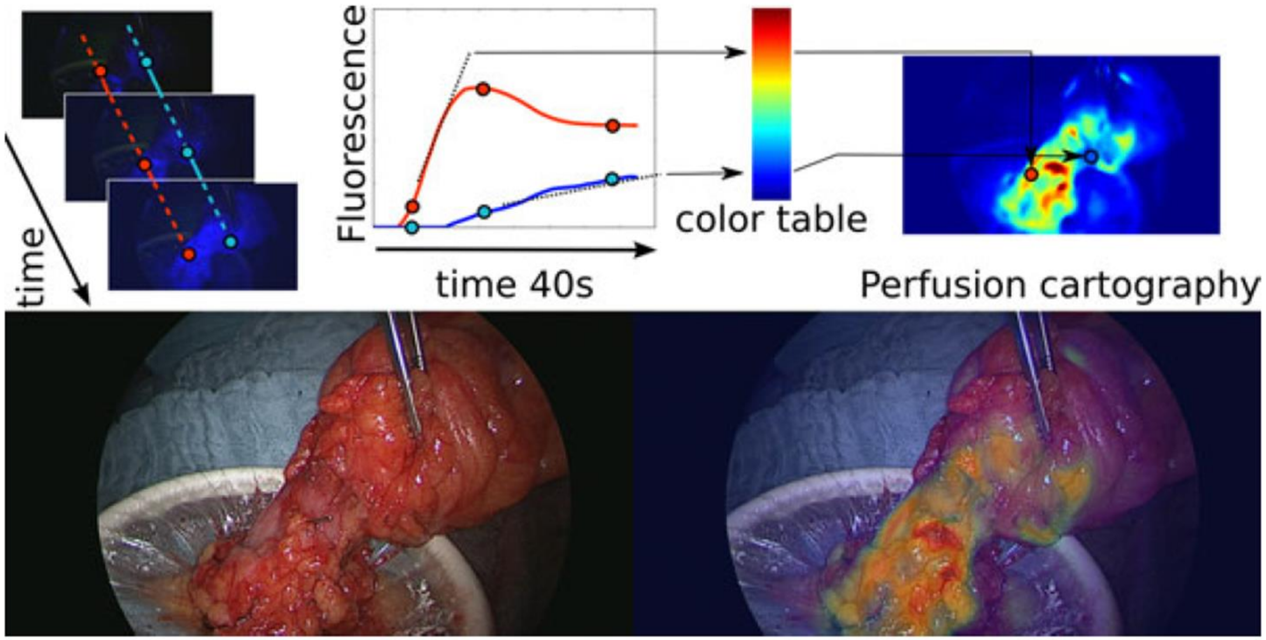
- projector-based overlay of the VR model on the real patient – transparency visualization / screen based visualization of the virtual model demonstrating the position of the liver tumor (green) by transparency



Mascagni P, et al. *J Surg Oncol 2018*

FLEER – Fluorescence-based enhanced reality

- to evaluate bowel perfusion; the VR-perfusion software calculates the slope of the fluorescence time-to peak, which is converted to a virtual perfusion cartogram
- white light image is merged with the perfusion cartography obtaining an AR-view of the bowel perfusion



Mascagni P, et al. *J Surg Oncol 2018*

Hyperspectral Imaging (HSI)

- Developed in the 1960‘s from the

- <u>Current applications:</u>

  -Aerospatial sensing

  -Recycling

  -Industrial (material‘s quality and quantity)

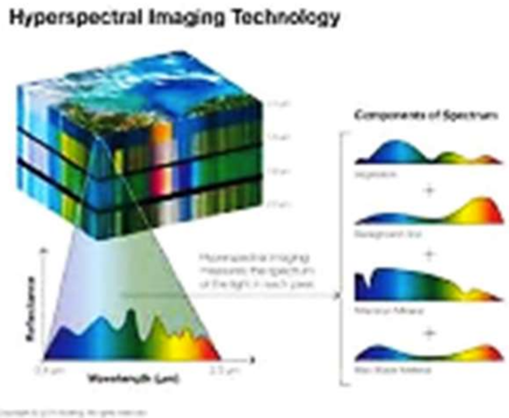
  -Vegetation

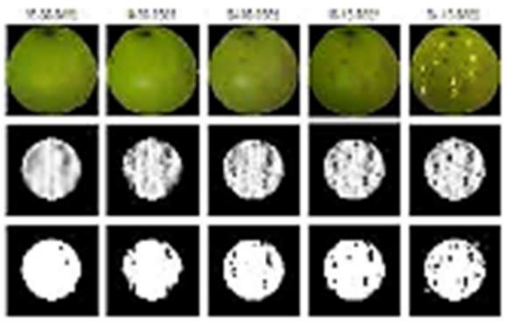
  -Fruit contamination and quality control

  -Archeology

  -Crime scene detection

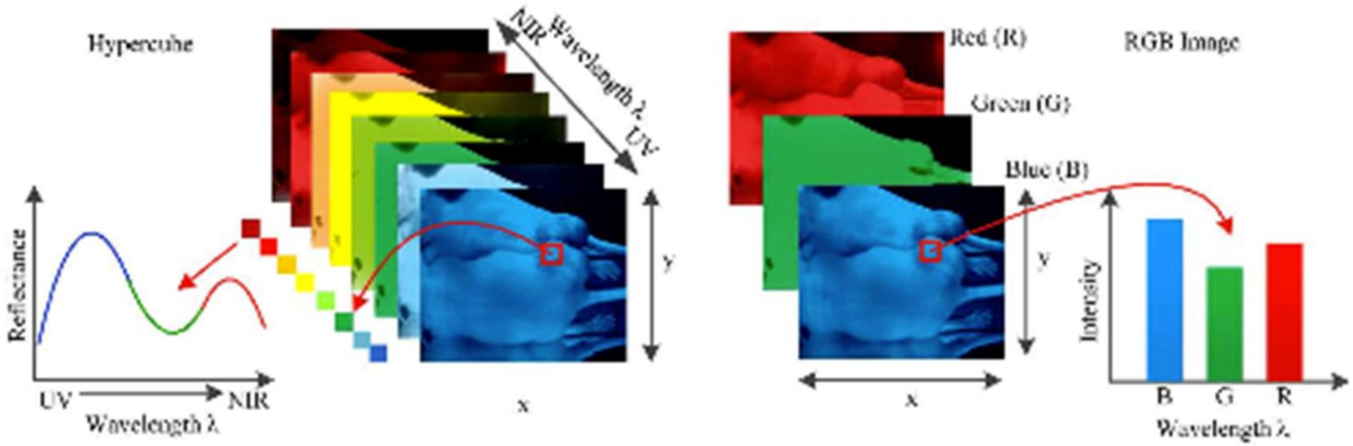
  -Food sorting / agriculture





HSI technology

- non-invasive tissue analysis



Pros:

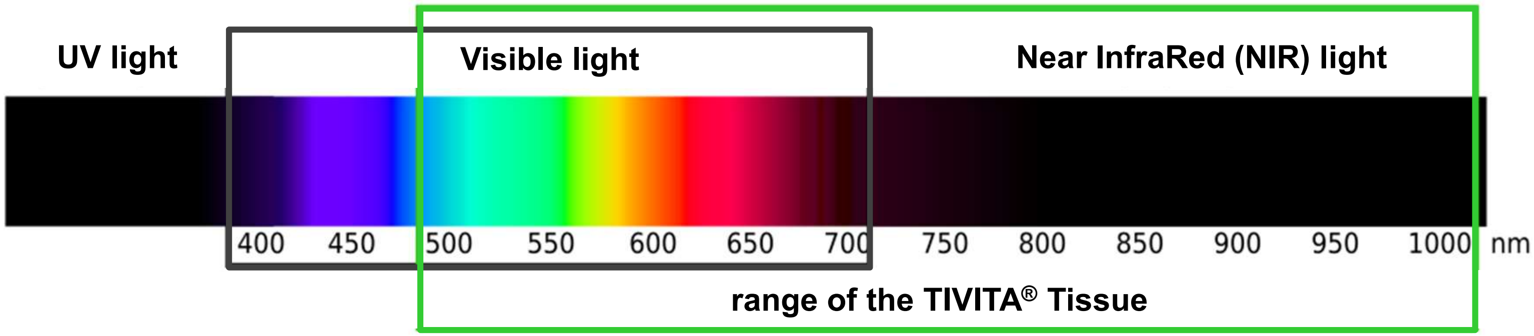
- *Noninvasive manner and in real time*
- *Broad range: range from UV to IR region*
- *Objectivation through spectral curves*
- *No contrast needed*

Cons:

- *Complex information extraction*
- *Expensive systems*
- *Usually bulky hardware*
- *No available video systems*

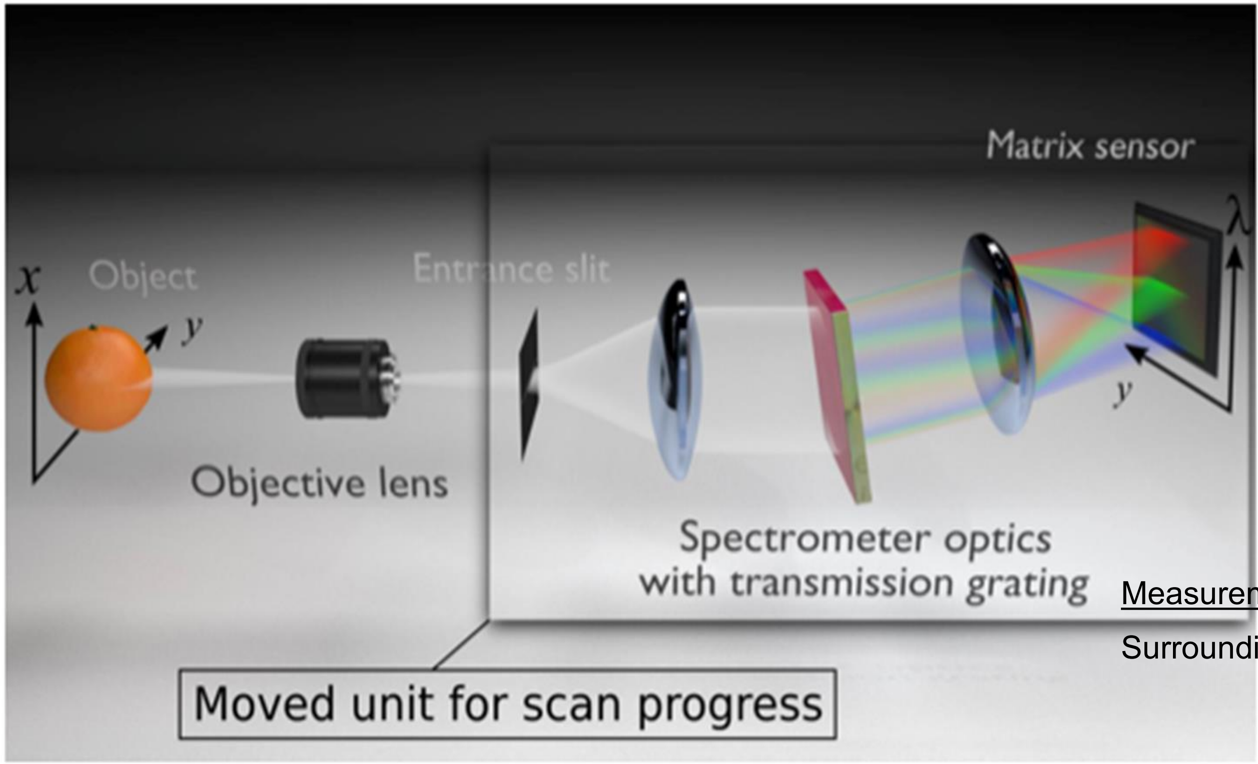
Basics of technology I

- Electromagnetic waves – absorption spectroscopy
- Human eye / usual cameras multispectral – 3 channels: Red, Green, Blue (RGB)
- Multispectral camera with 4-8 channels
- Hyperspectral, optical measurement with 100 colour channels in the range of 500-1000 nm
- Non-invasive, contactless, fast and reliable
- Camera works like an imaging tissue oxymeter



Basis of technology II

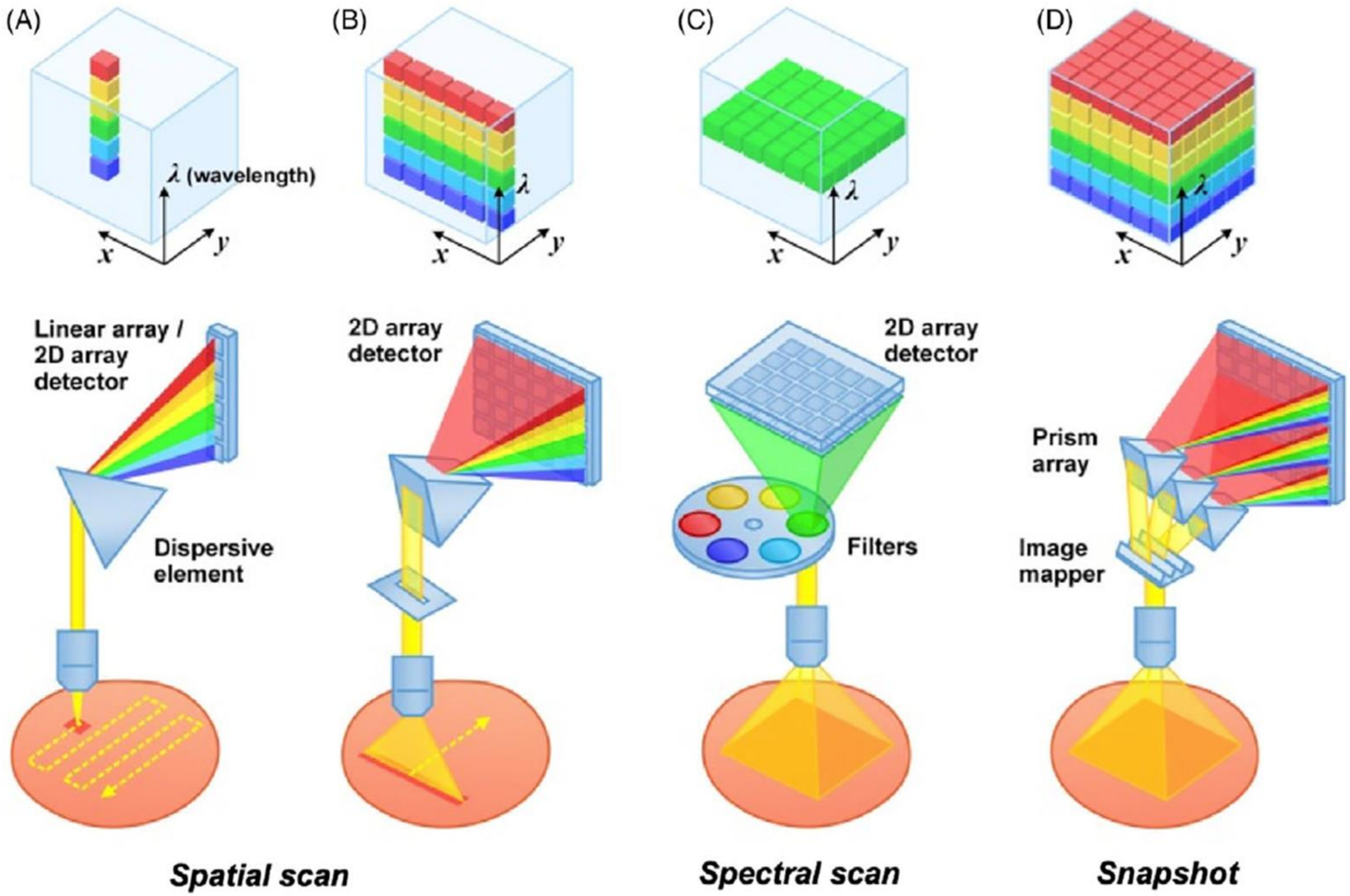
- schematic representation of the HSI camera system



Measurement conditions:

Surroundings:	as little external light as possible
	no dressings or clothes
	as little liquids as possible
Distance:	50 cm
Time of measurement:	6,4 s
Time of processing:	18 s
Result:	30 s

Hyperspectral imaging aquisition methods



Point scan
Spectral res: high
Speed: low

Line scan
Spectral res: high
Speed: medium

Wavelength scan
Spectral res: low - high
Speed: medium/high

Snapshot scan
Spectral res: low - high
Speed: medium/high

Shapey J, et al. *J Biophotonics 2019*

Camera technology

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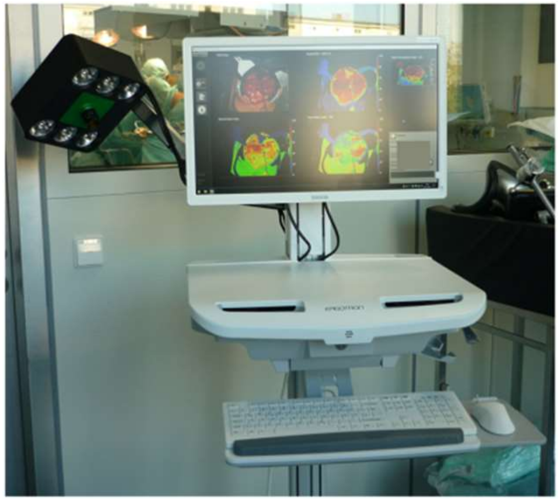
- Camera-technology for recording and visual representation of chemical tissue information



Basis of technology III

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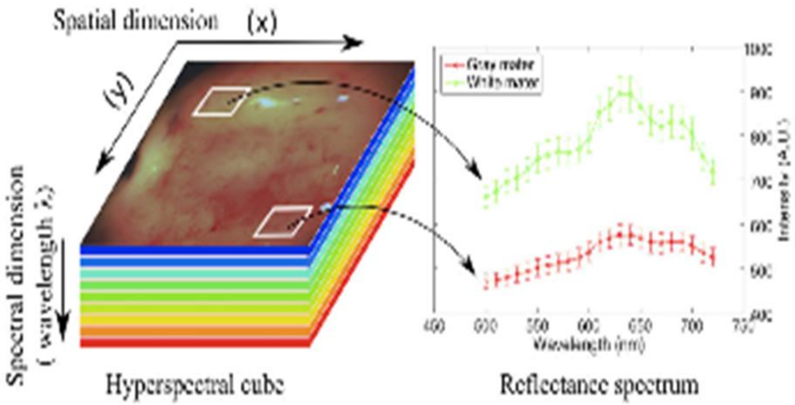
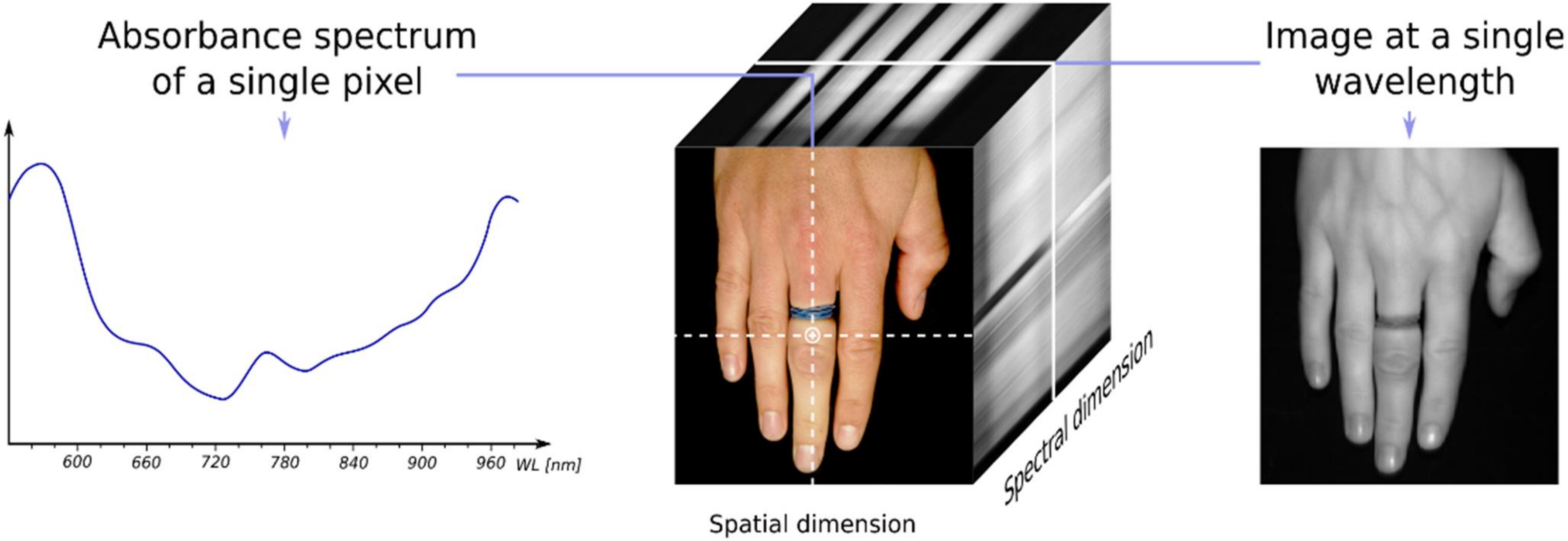
Hyperspectral cube



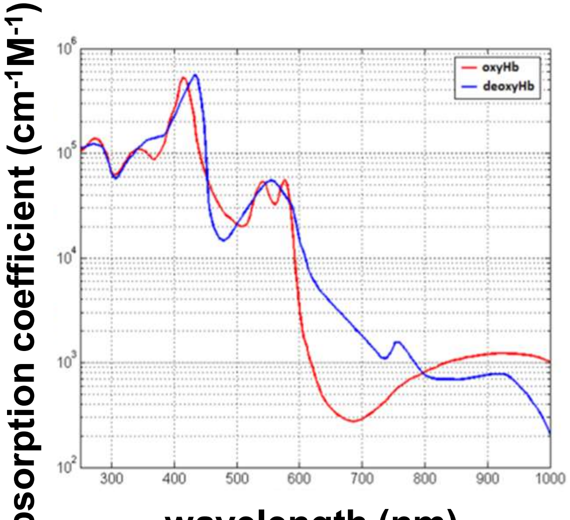
Shapey J, et al. *J Biophotonics 2019*



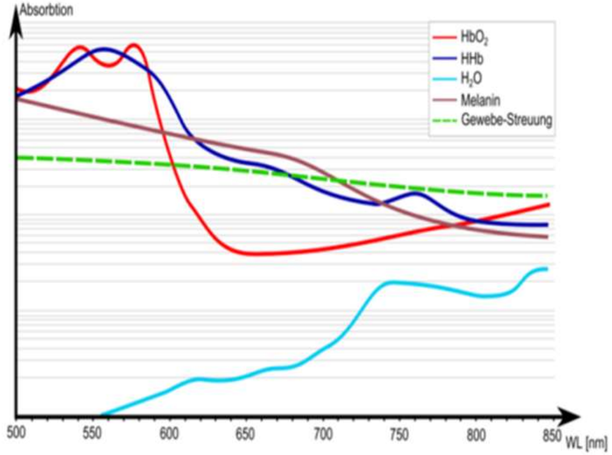
-> spectral signatures can be generated for specific tissues

Recording of spectral measurement data

- Known spectra
- Knowledge of scattering and absorption properties
- Presence, quantity & state of the components
- green: TIVITA®; orange: pulse oxymeter



absorption spectra hemoglobin



relevant components

Current parameters of spectral measurement

- **Oxygenation of Hemoglobin – StO_2:**

  Visual range of the light (VIS), superficial

- **Tissue Hemoglobin Index – THI:**

  VIS range, superficial

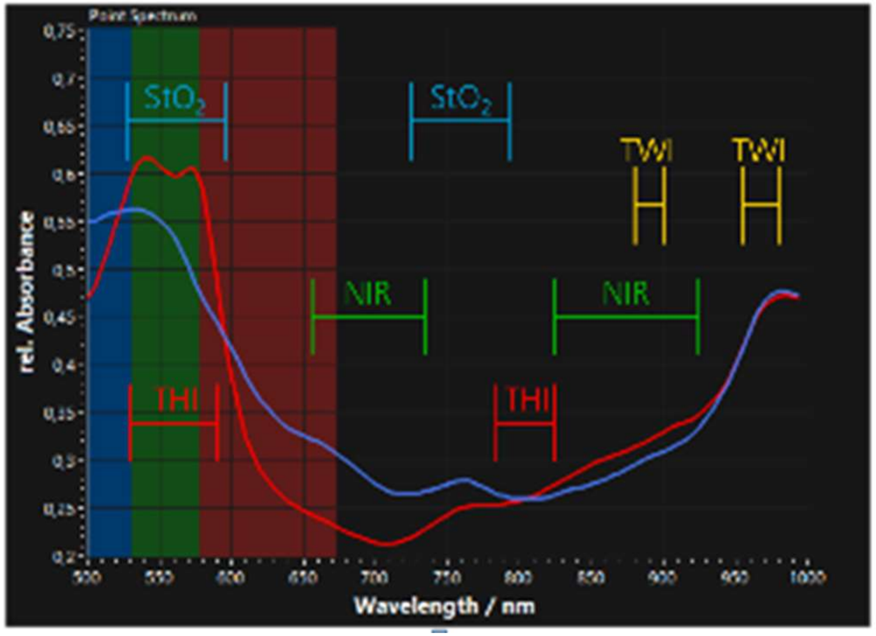
- **Near InfraRed (NIR)-Perfusion:**

  NIR range, oxygenation in deeper layers

- **Tissue Water Index – TWI:**

  NIR range, oxygenation in deeper layers

absorption spectra hemoglobin **relevant components**



Recording of spectral measurement data I

RGB image (color image)

Color image calculated from the recorded spectra similar to a normal photo but with objective comparable color

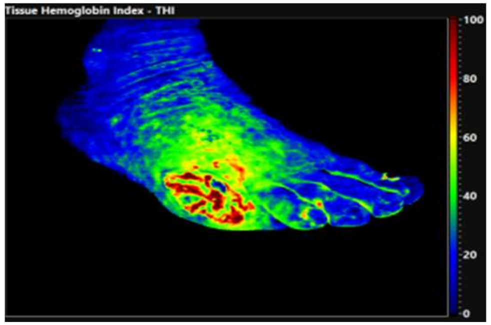
HI / OHI image

Relative volume fraction & distribution of hemoglobin in the viewed image area

Color scale:

Red (high hemoglobin content) to

Blue (low hemoglobin content)



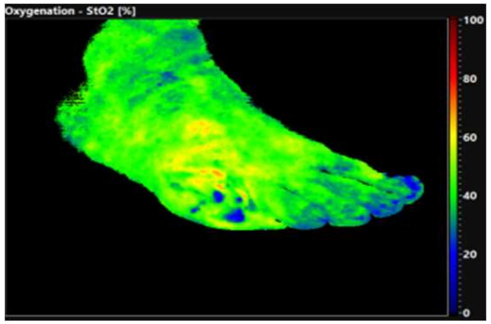
Oxygenation image

Oxygen saturation of the hemoglobin distributed in the tissue

Color scale:

Red (high oxygenation) to

Blue (low oxygenation)



Recording of spectral measurement data II

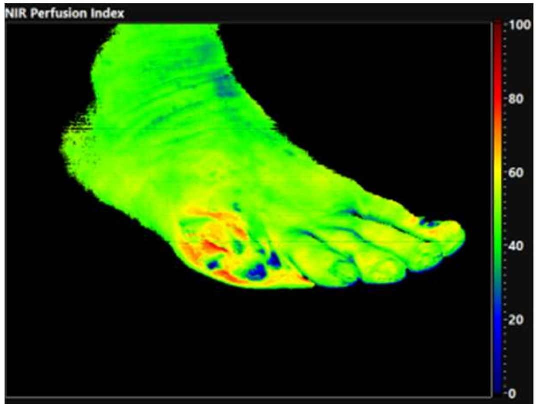
NIR Perfusion image

Describes the oxygenation of deeper layers of the tissue

Color scale:

Red (high perfusion) to

Blue (low perfusion)



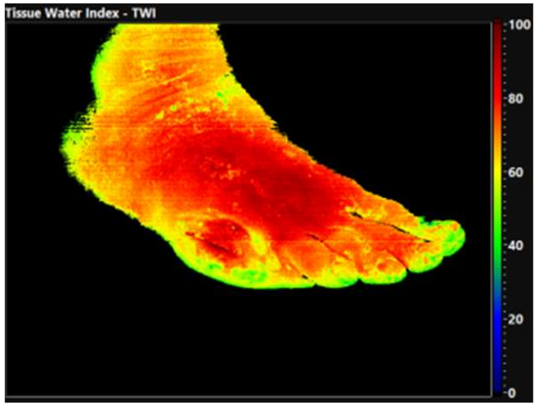
TWI image

Distribution of the tissue water in the viewed image area

Color scale:

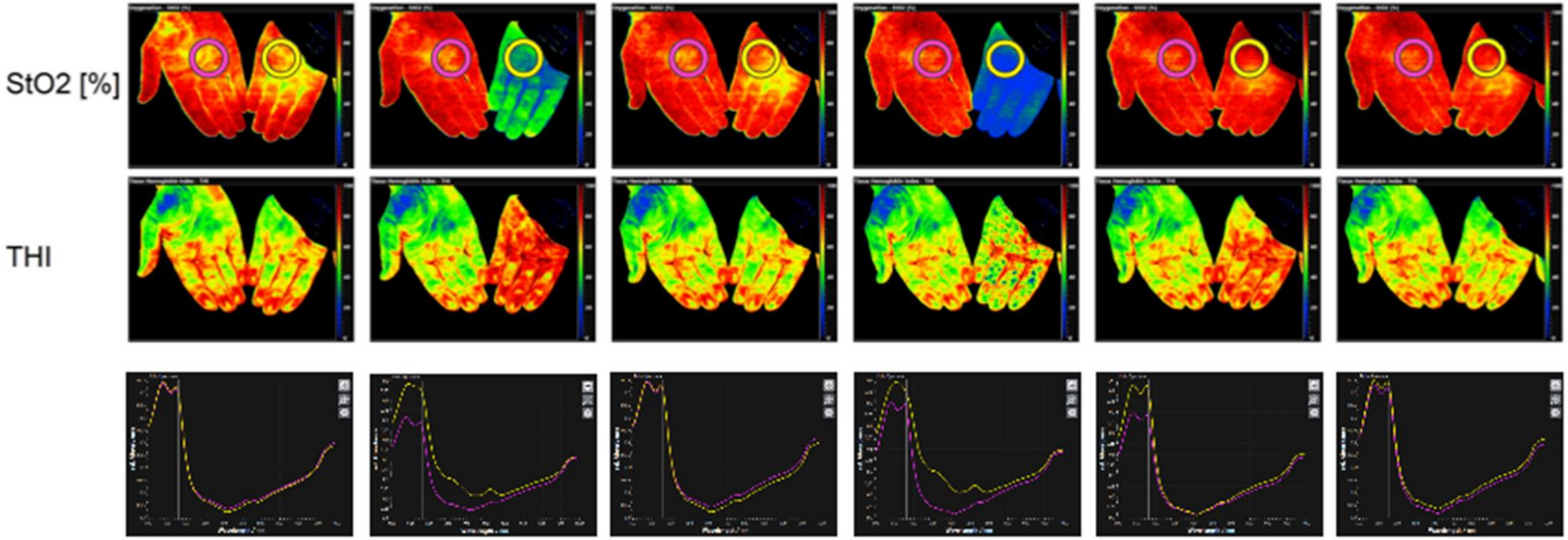
Red (high water content) to

Blue (low water content)



Recordings of spectral measurement data III

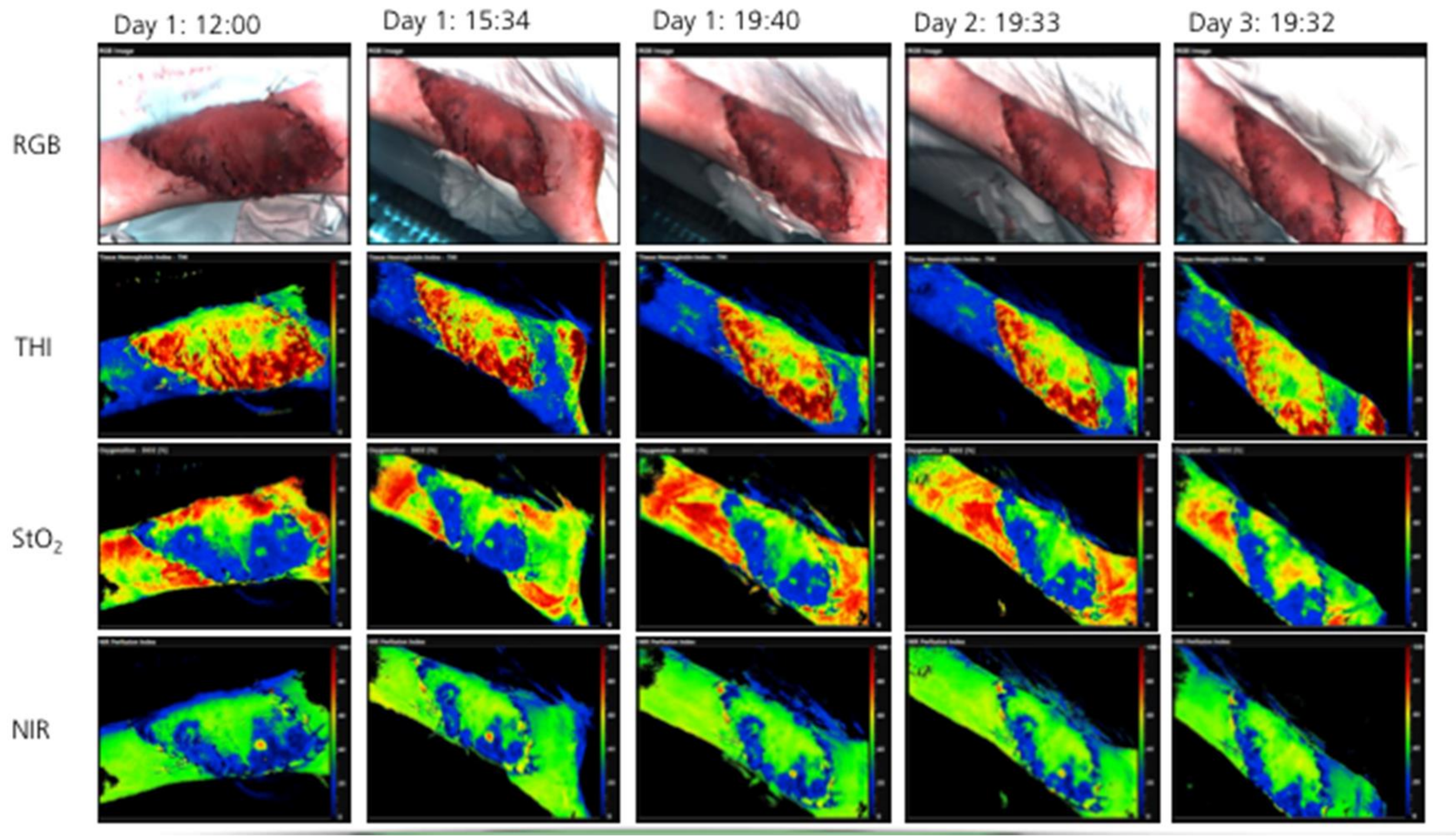
- Occlusion-study for validation



Clinical applications I

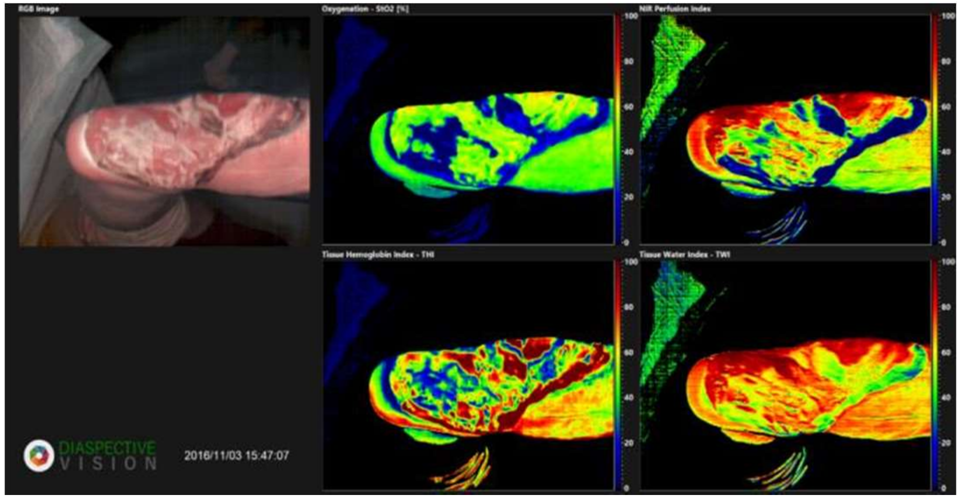
- Optimum Monitoring process
- Blood of flap unequally distributed
- Perforator
- Connection via fat tissue
- Venous Occlusion

Case studies: Flap transplantation



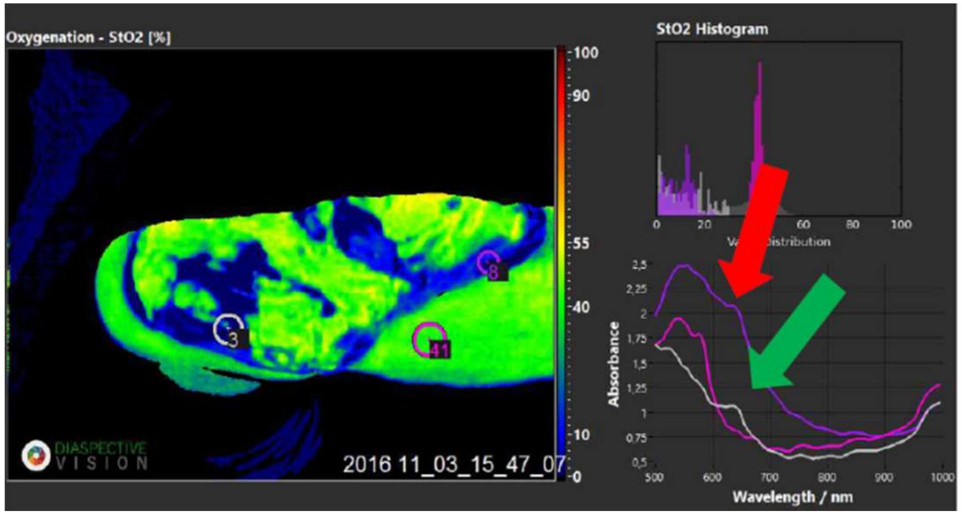
Clinical applications II

- Wound-imaging



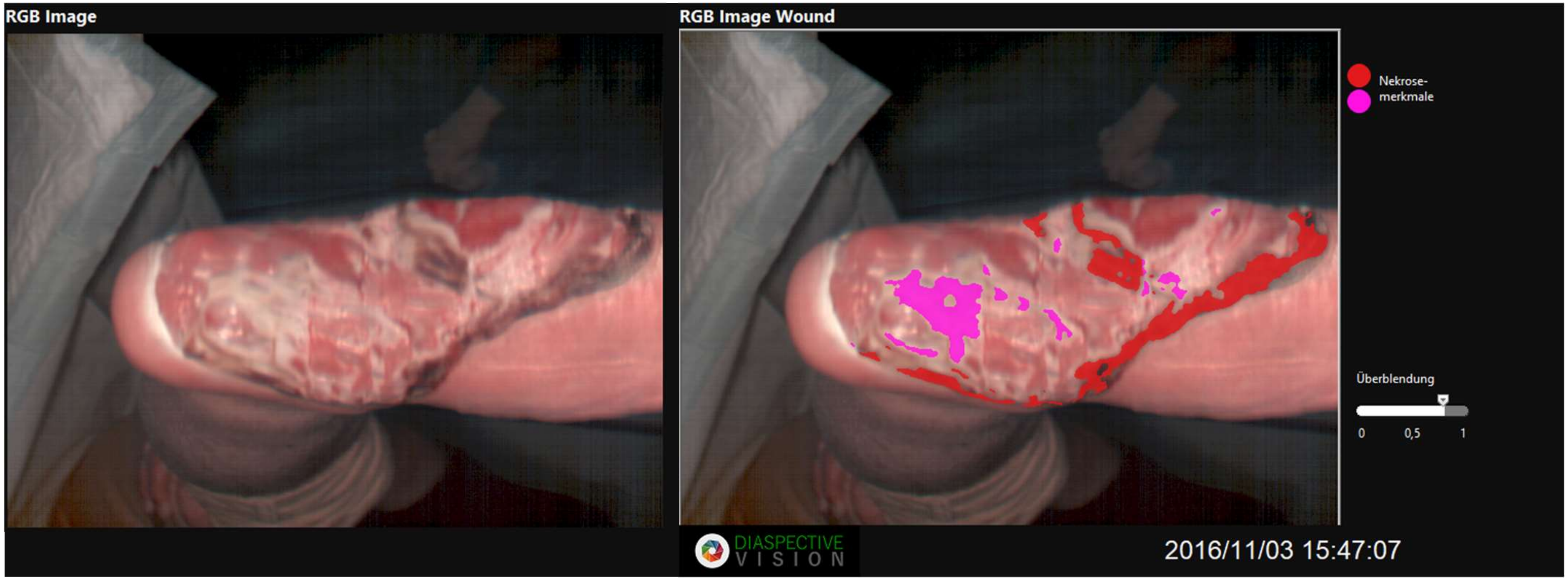
visual: clear necroses (black), undefined areas

HSI: necrotic areas that are not visually recognizable, white necroses



Clinical applications III

- Wound-imaging



HSI in gastrointestinal anastomoses

- anastomotic evaluations: perfusion, oxygenation, water content

Chirurg 2018 · 89:717–725
https://doi.org/10.1007/s00104-018-0633-2
Online publiziert: 10. April 2018

CrossMark

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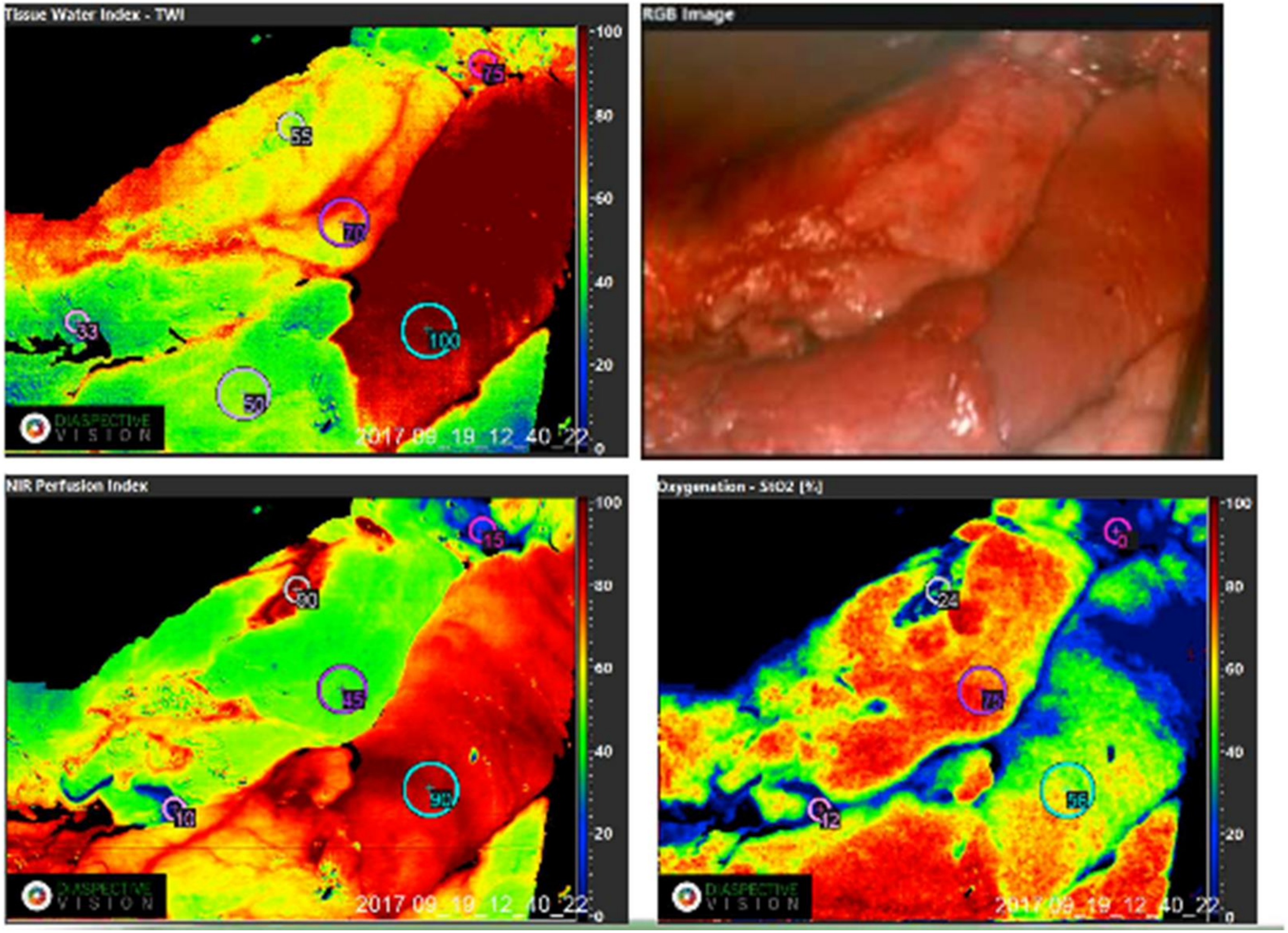
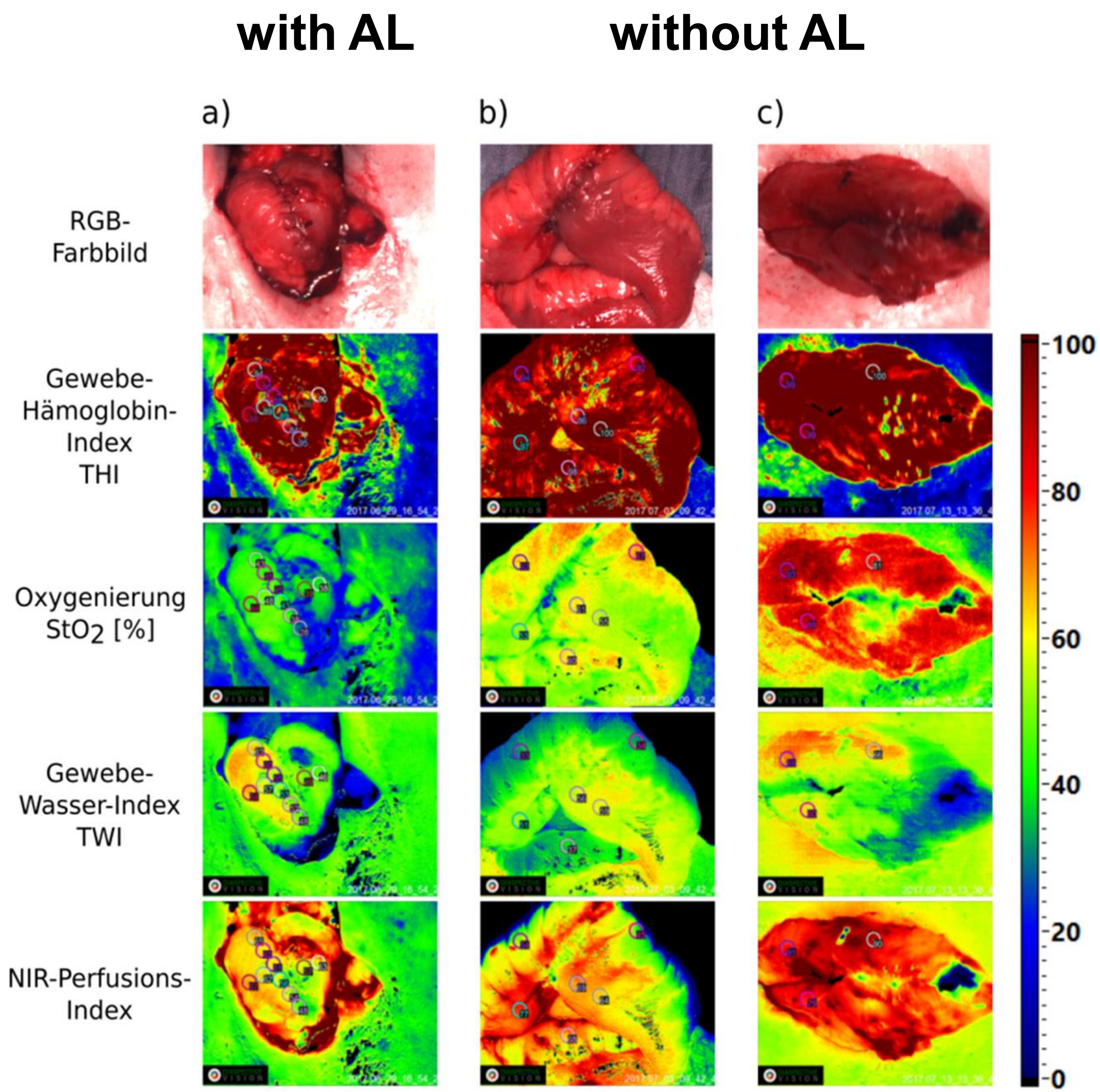
Hyperspektral-Imaging bei gastrointestinalen Anastomosen

Jansen-Winkeln B... Gockel I, *Chirurg 2018*

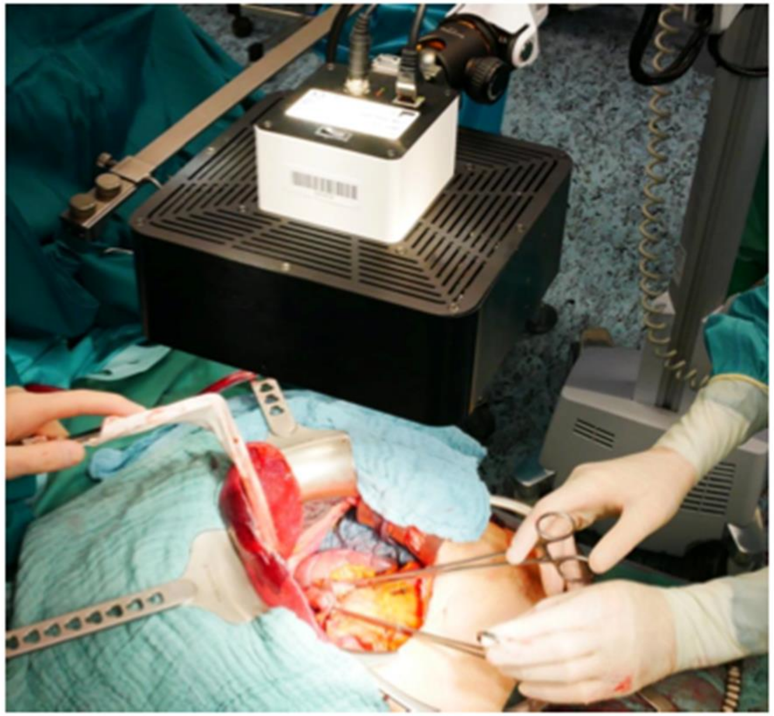
HSI-application in GI-anastomoses I

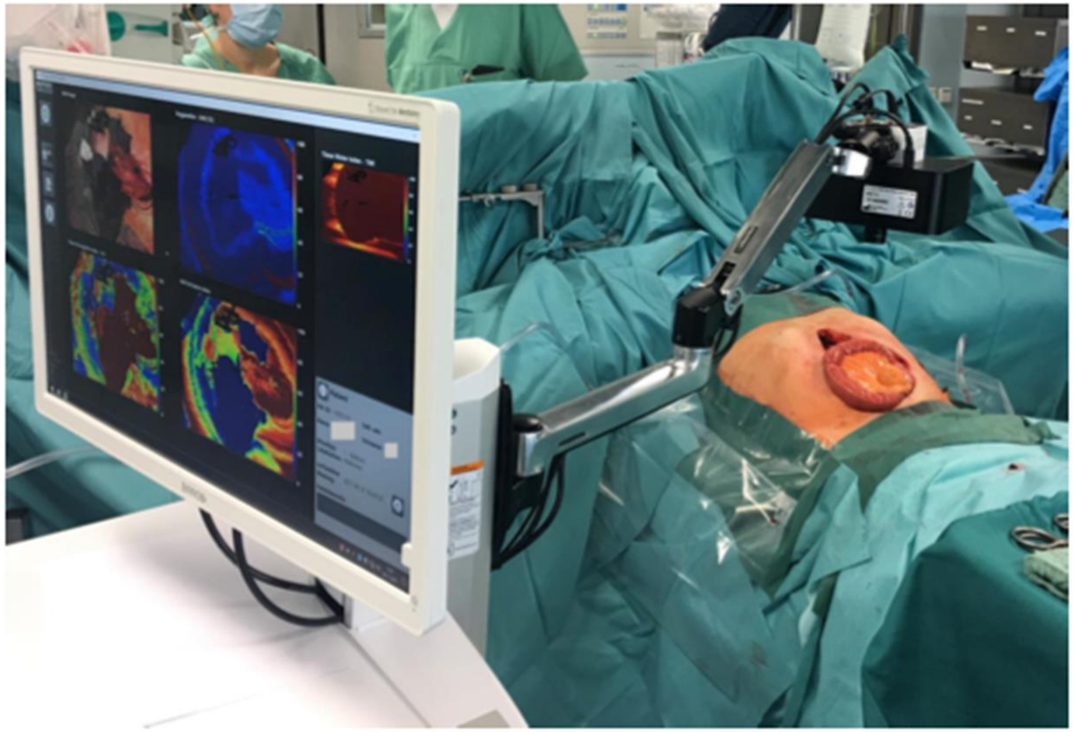


HSI-application in GI-anastomoses II



Current limitations: Camera size in minimally invasive procedures





Measurements via mini-laparotomy in MIS

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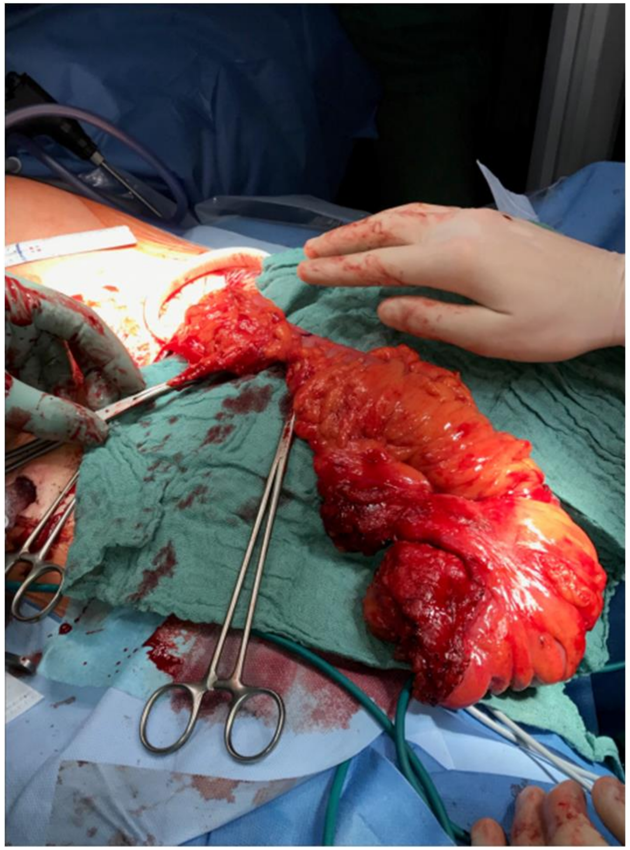
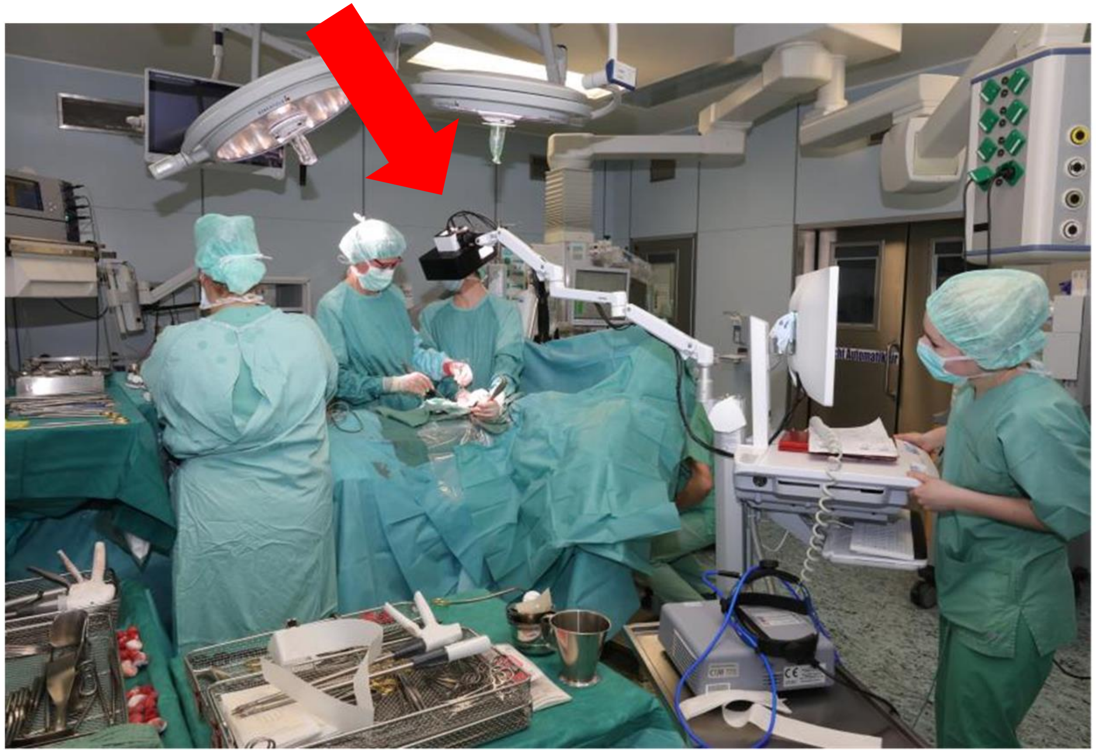
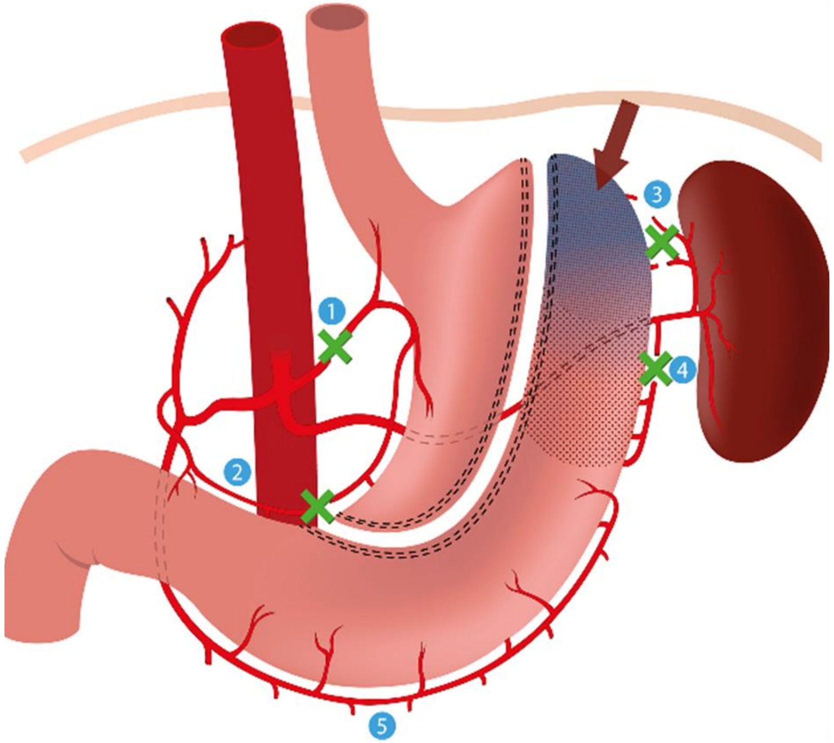
- Mini-laparotomy: extracorporeal phase





‚Key Point‘: Perfusion of the proximal gastric tube during esophagectomy



Intrathoracic anastomosis

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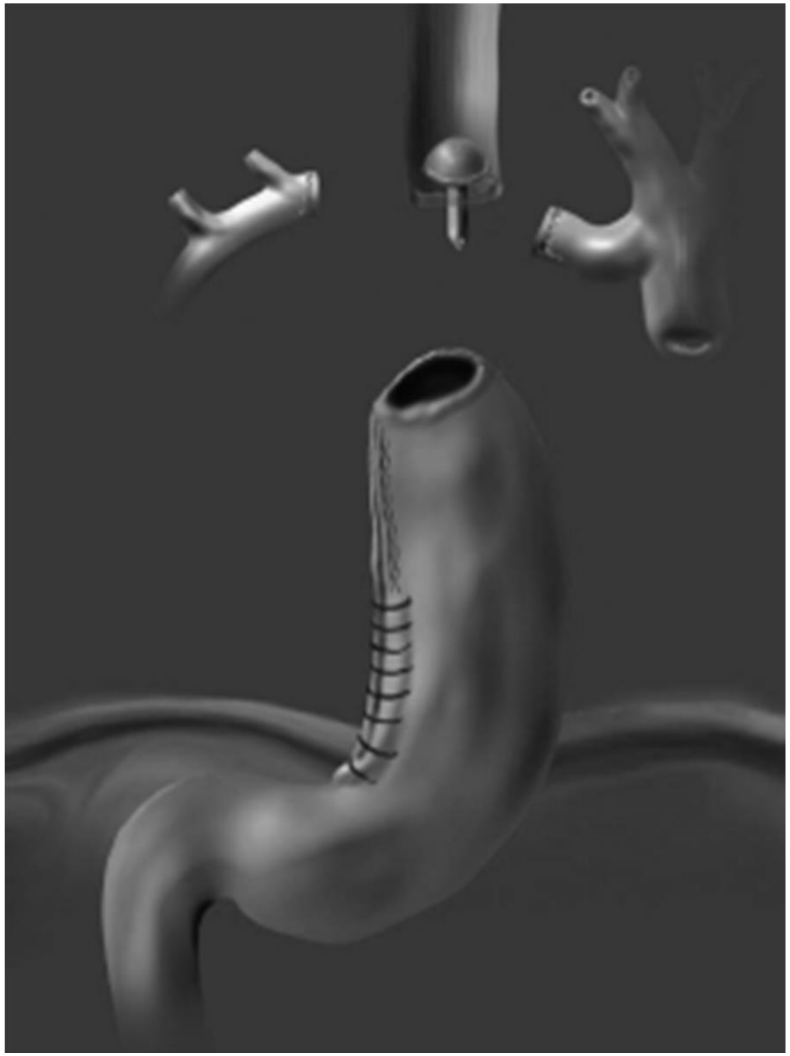

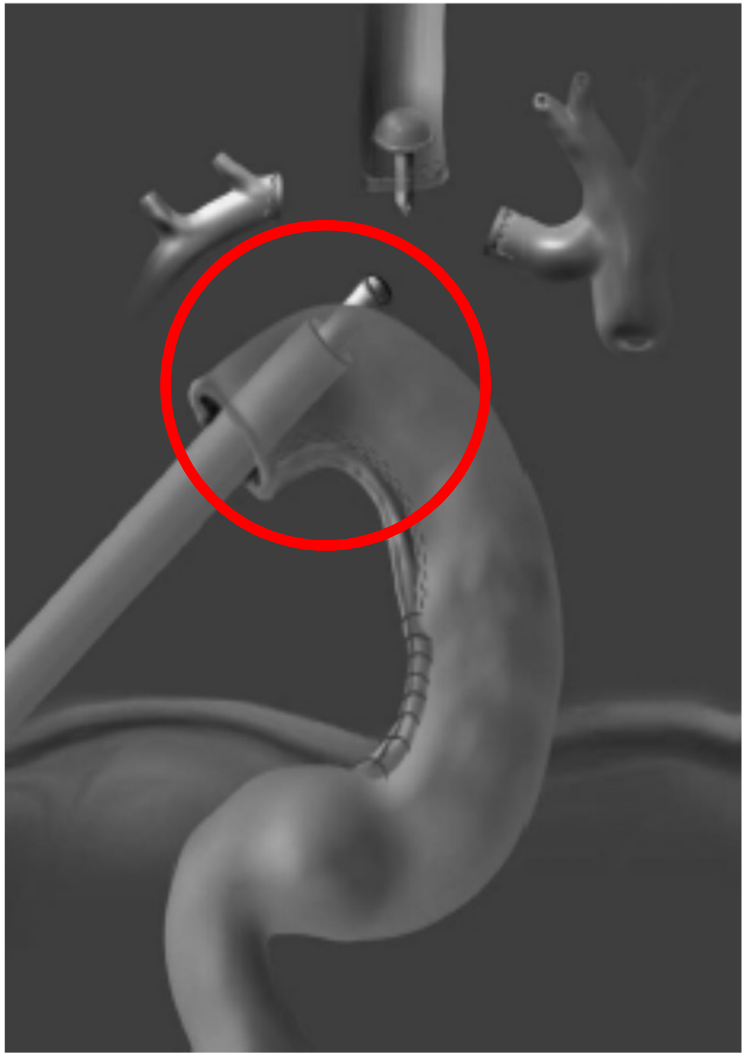

Nguyen NT, et al. *Ann Surg 2008*

HSI-measurement of the gastric tube

Analysis of HSI-parameters in the area of the later anastomosis

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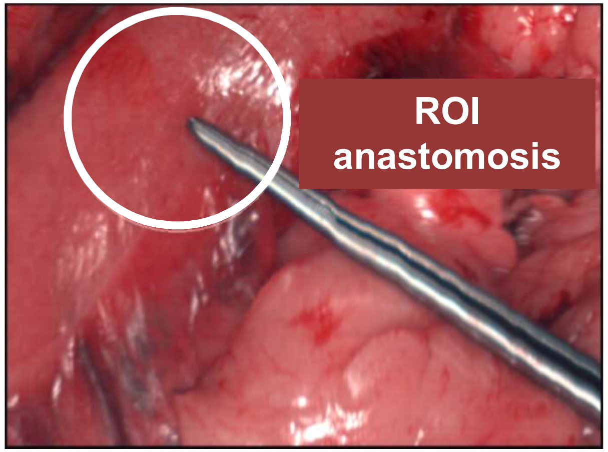
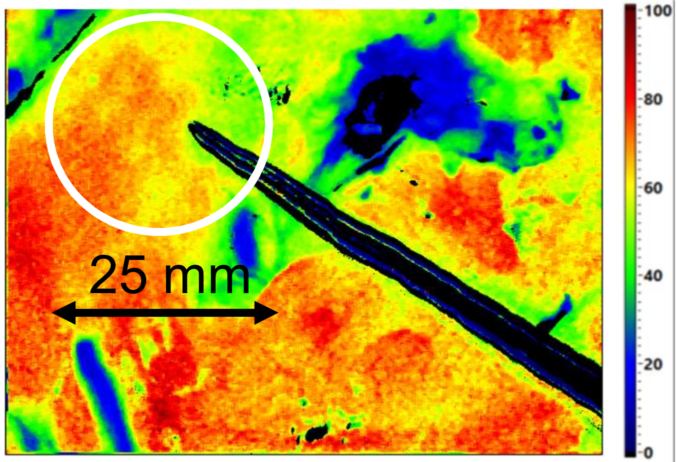


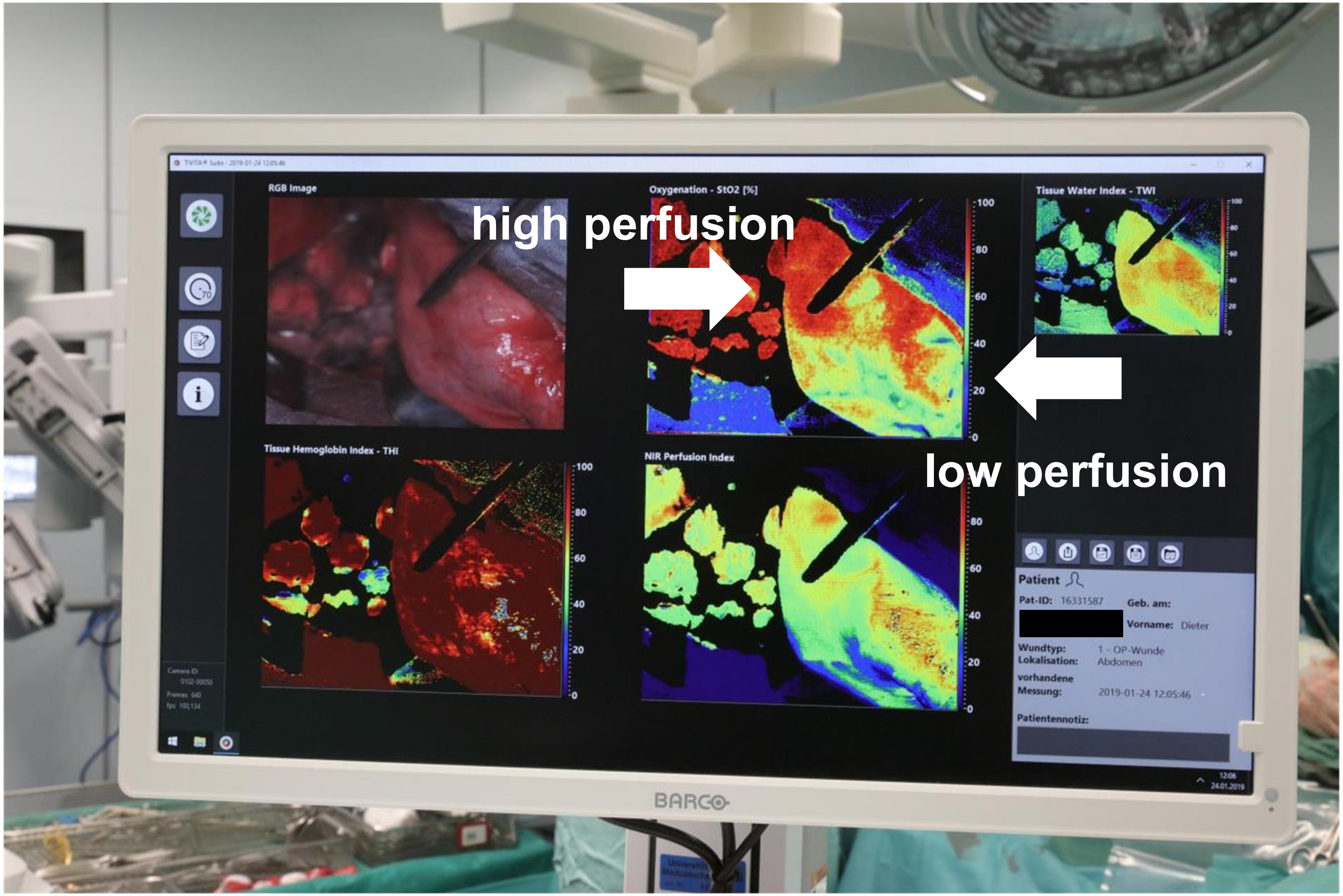
Oxygenation (StO_2)



$StO2_{ROI} = 62\%$

mean ROI in n=30 patients

Discrimination of areas with high and low perfusion



HSI-evaluation of the gastric tube

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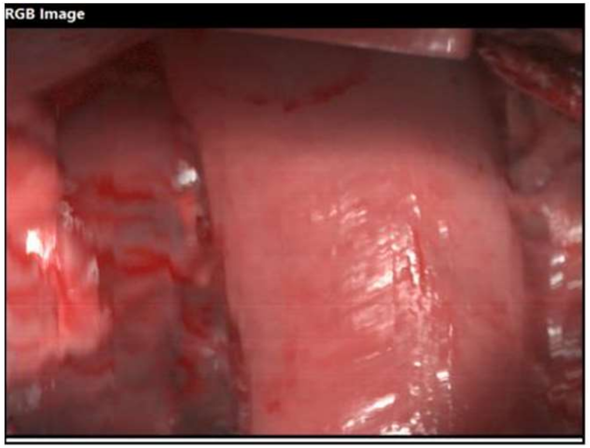
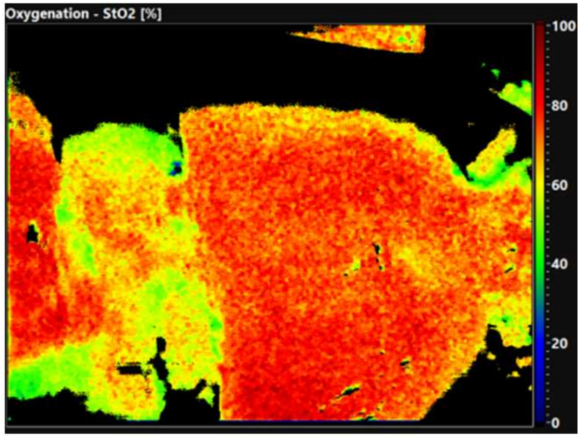
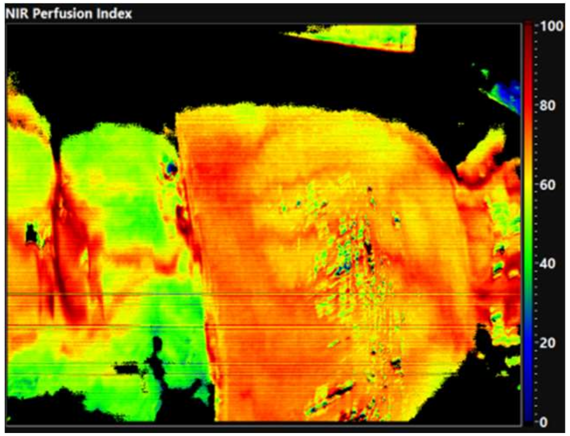
RGB-image



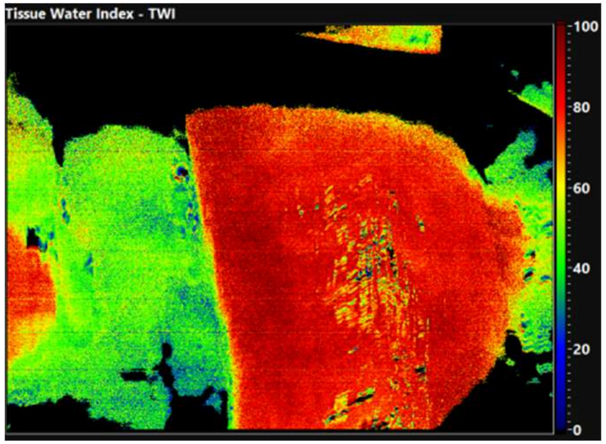
Oxygenation (StO_2)



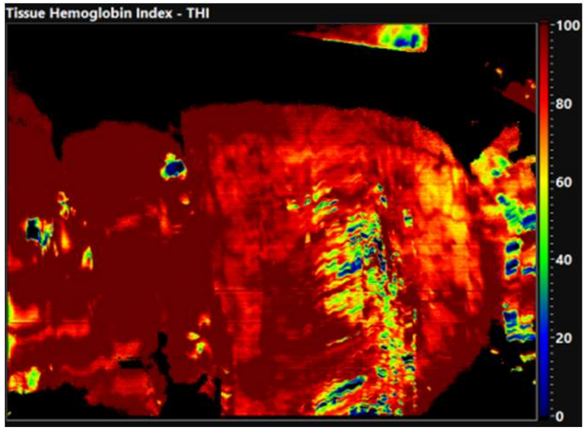
NIR-Perfusion-Index



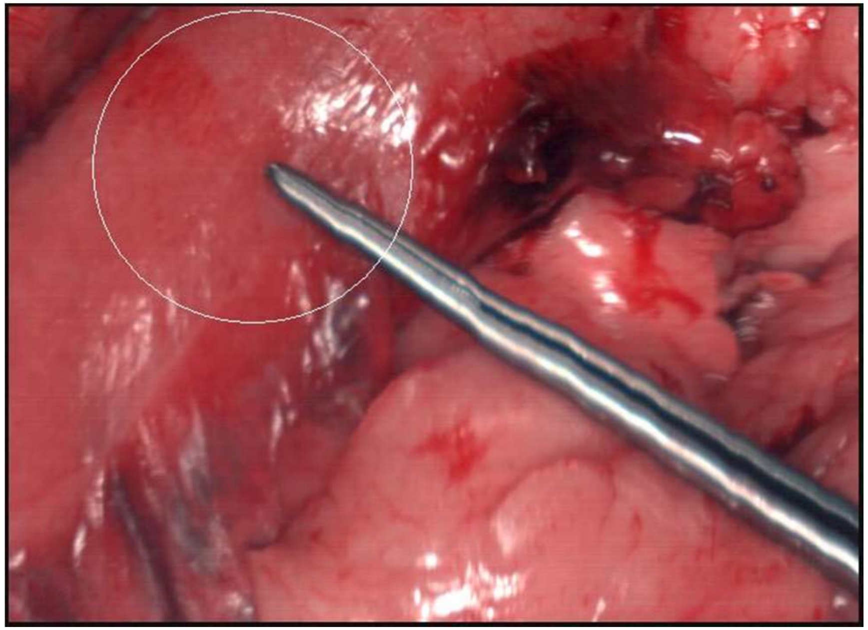
Tissue Water-Index

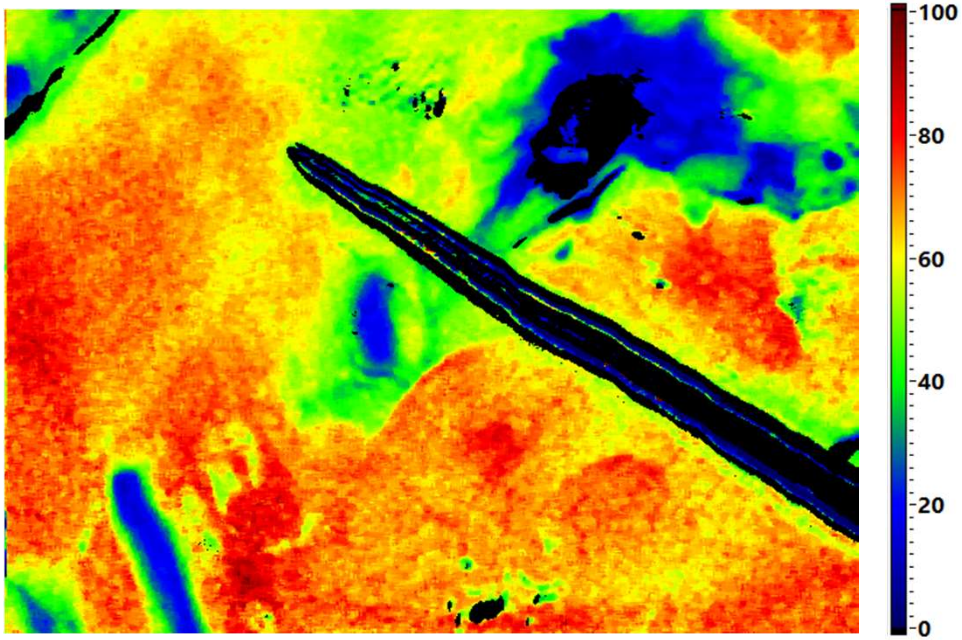


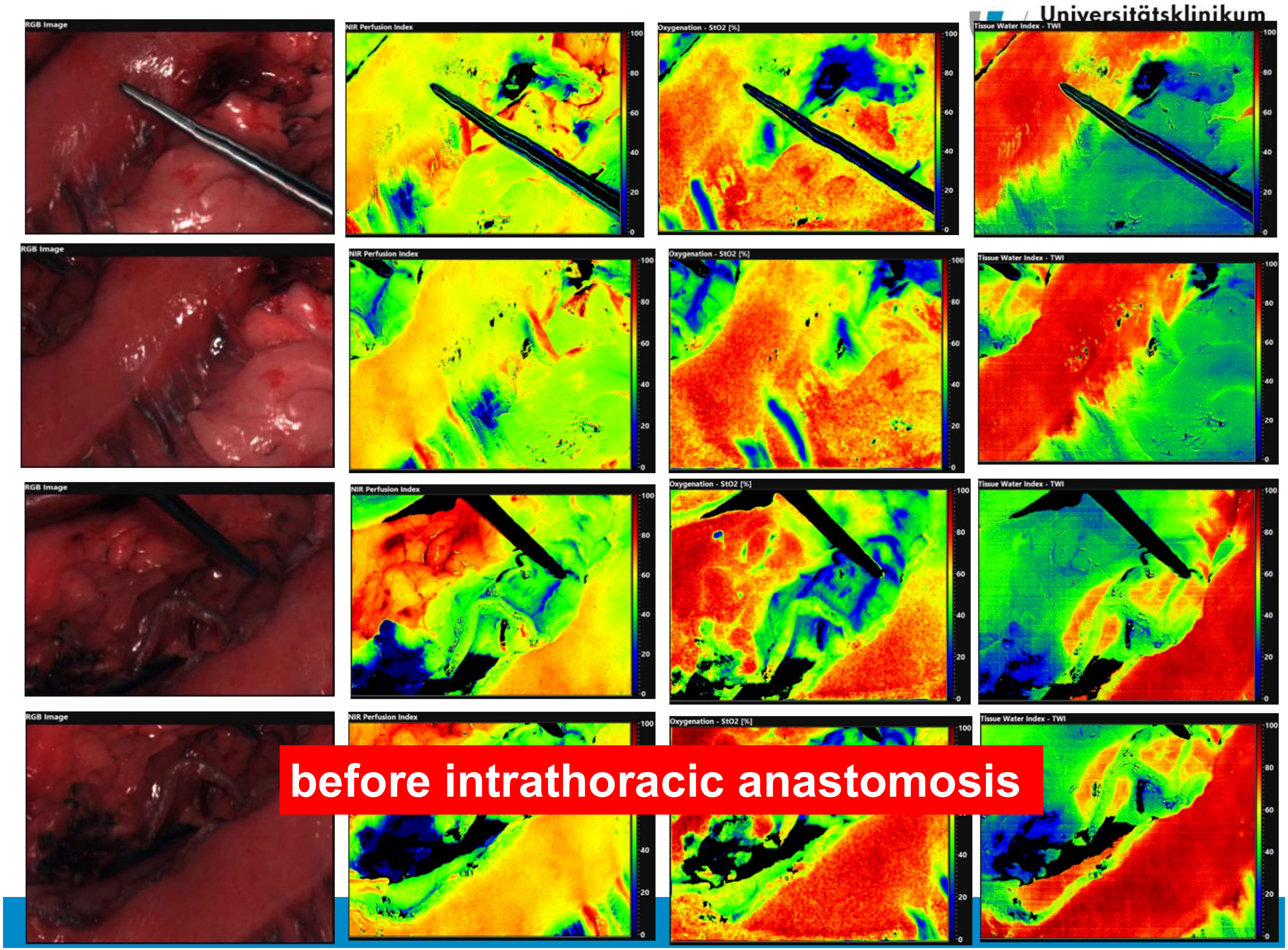
Tissue Hemoglobin-Index

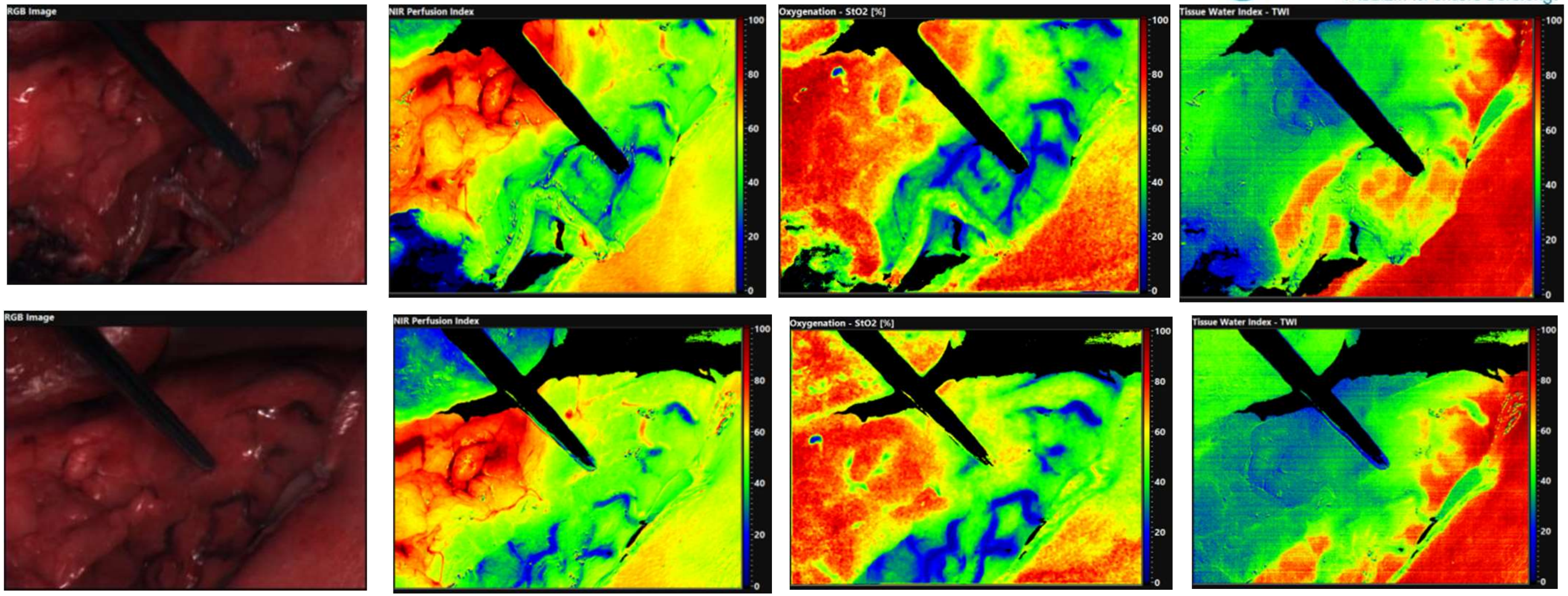


HSI-evaluation of the gastric tube





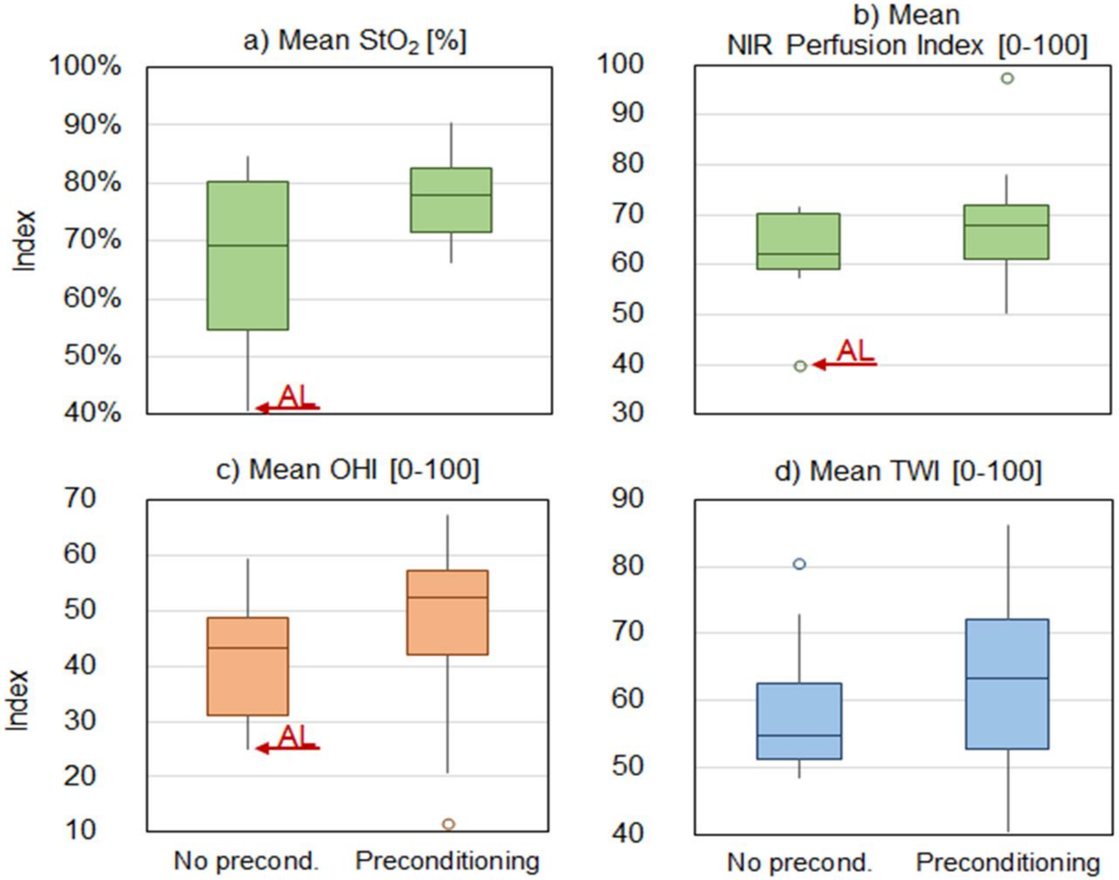

Universitätsklinikum
RGB Image
NIR Perfusion Index
Oxygenation - StO2 [%]
Tissue Water Index - TWI
100
80
60
40
20
0
before intrathoracic anastomosis



after intrathoracic anastomosis

Gastric tube: HSI-results I

Tissue oxygenation of the gastric tube was significantly higher in patients with ischemic conditioning (P=0.03)



Köhler H,...Gockel I, et al. *Surg Endosc 2019*

Decreased Conduit Perfusion Measured by Spectroscopy Is Associated With Anastomotic Complications

Thai H. Pham, MD, Kyle A. Perry, MD, C. Kristian Enestvedt, MD, Dan Gareau, PhD, James P. Dolan, MD, Brett C. Sheppard, MD, Steven L. Jacques, PhD, and John G. Hunter, MD

Department of Surgery, Veterans Affairs Medical Center North Texas Health Care System, Dallas, Texas; Department of Surgery, Ohio State University, Columbus, Ohio; and Departments of Surgery and Biomedical Engineering, Oregon Health & Science University, Portland, Oregon

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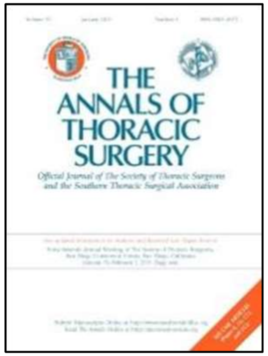
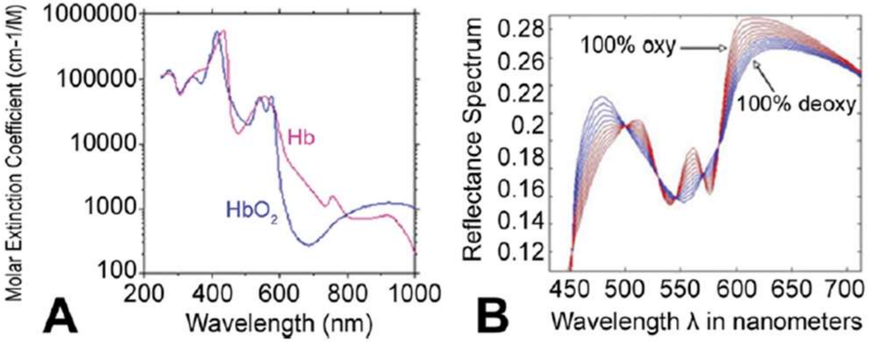


- OFS = Optical Fibre Spectroscopy (SaO_2)
- Blood Volume Fraction (BVF)



<u>measurements:</u>
- baseline
- after devascularization of the stomach
- after gastric tube formation
- after transposition of the gastric tube

-> correlation of SaO_2- / BVF-findings with clinical results

Pham TA, et al. *Ann Thorac Surg 2011*

(AV-) SaO_2- and BVF-changes in patients with and without ischemic conditioning

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	% SaO_2 (Mean + SD)*			% BVF (Mean + SD)*		
ischemic conditioning	**no**	**yes**	**P-value**	**no**	**[illegible]s**	**P-value**
short gastric vessels	88.6 ± 19.7	92.9 ± 11.2	0.69	[illegible]	[illegible].28	0.99
left gastric artery	74.4 ± 26.3	77.4 ± 31[illegible]	[illegible]	[illegible].59	0.96 ± 0.34	0.22
gastric tube formation	67.8 ± 37[illegible]	[illegible]	[illegible]	1.33 ± 0.66	0.99 ± 0.73	0.50
gastric tube transpo-sition	[illegible]	[illegible]2.4	0.25	1.56 ± 0.62	1.41 ± 0.53	0.63

extent of intraoperative ischemia of the gastric tube is associated with postoperative anastomotic complications

*relation in % to the basic value

Pham TA, et al. *Ann Thorac Surg 2011*

LYSIS-project = laparoscopic hyperspectral system

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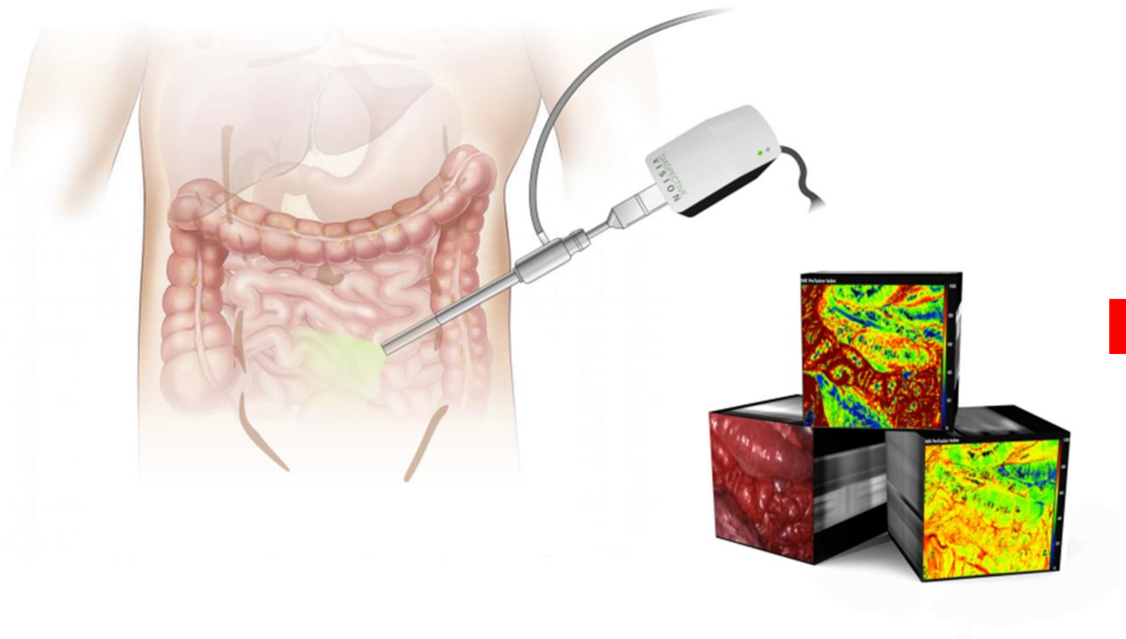

DIASPECTIVE VISION

iccas

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Determination of the transection margin in colorectal resection with HSI

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International Journal of Colorectal Disease (2019) 34:731–739
https://doi.org/10.1007/s00384-019-03250-0

ORIGINAL ARTICLE

CrossMark

Determination of the transection margin during colorectal resection with hyperspectral imaging (HSI)

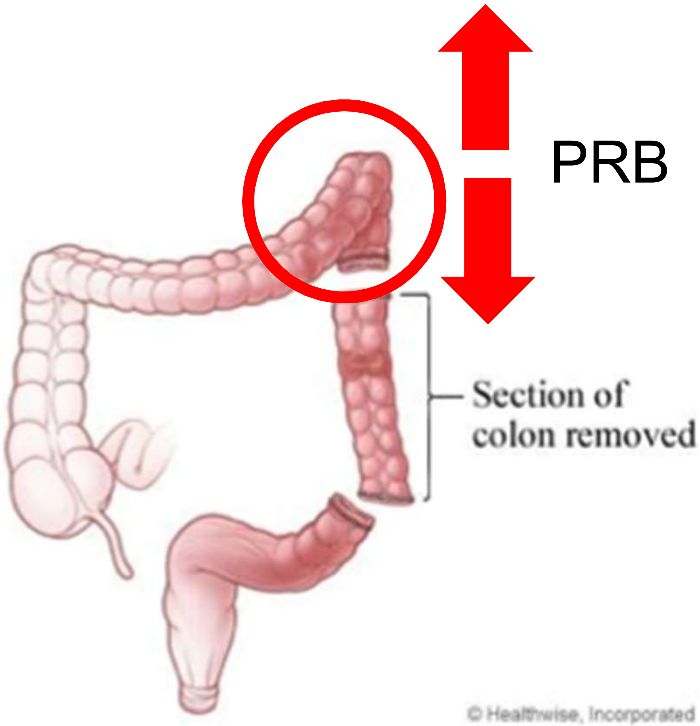
Boris Jansen-Winkeln[1] · N. Holfert[1] · H. Köhler[2] · Y. Moulla[1] · J. P. Takoh[1] · S. M. Rabe[1] · M. Mehdorn[1] · M. Barberio[1,3] · C. Chalopin[2] · T. Neumuth[2] · I. Gockel[1]

Accepted: 15 January 2019 / Published online: 2 February 2019

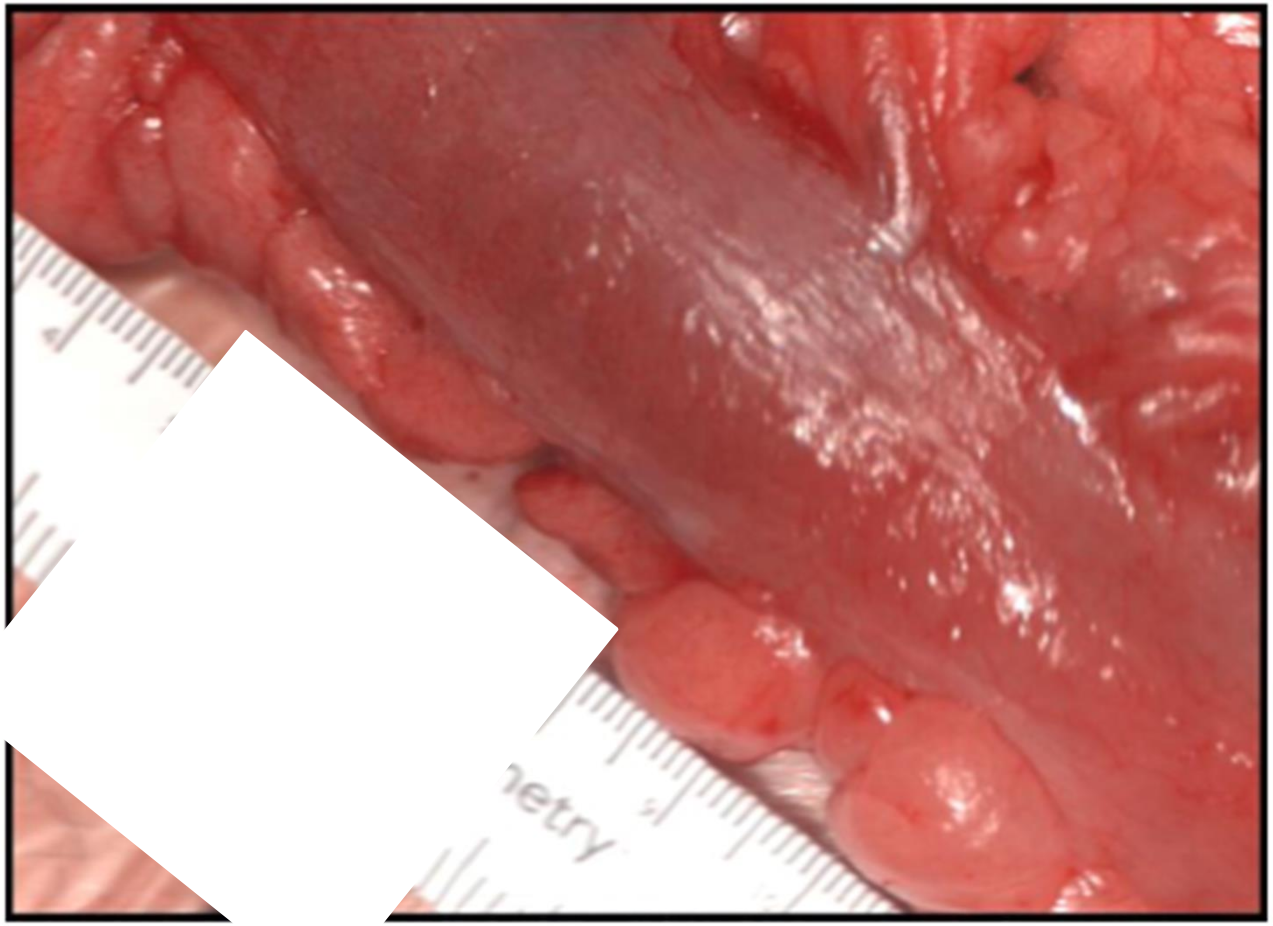
Jansen-Winkeln B, ...Gockel I, *Int J Colorect Dis 2019*

Proximal Resection Border (PRB)

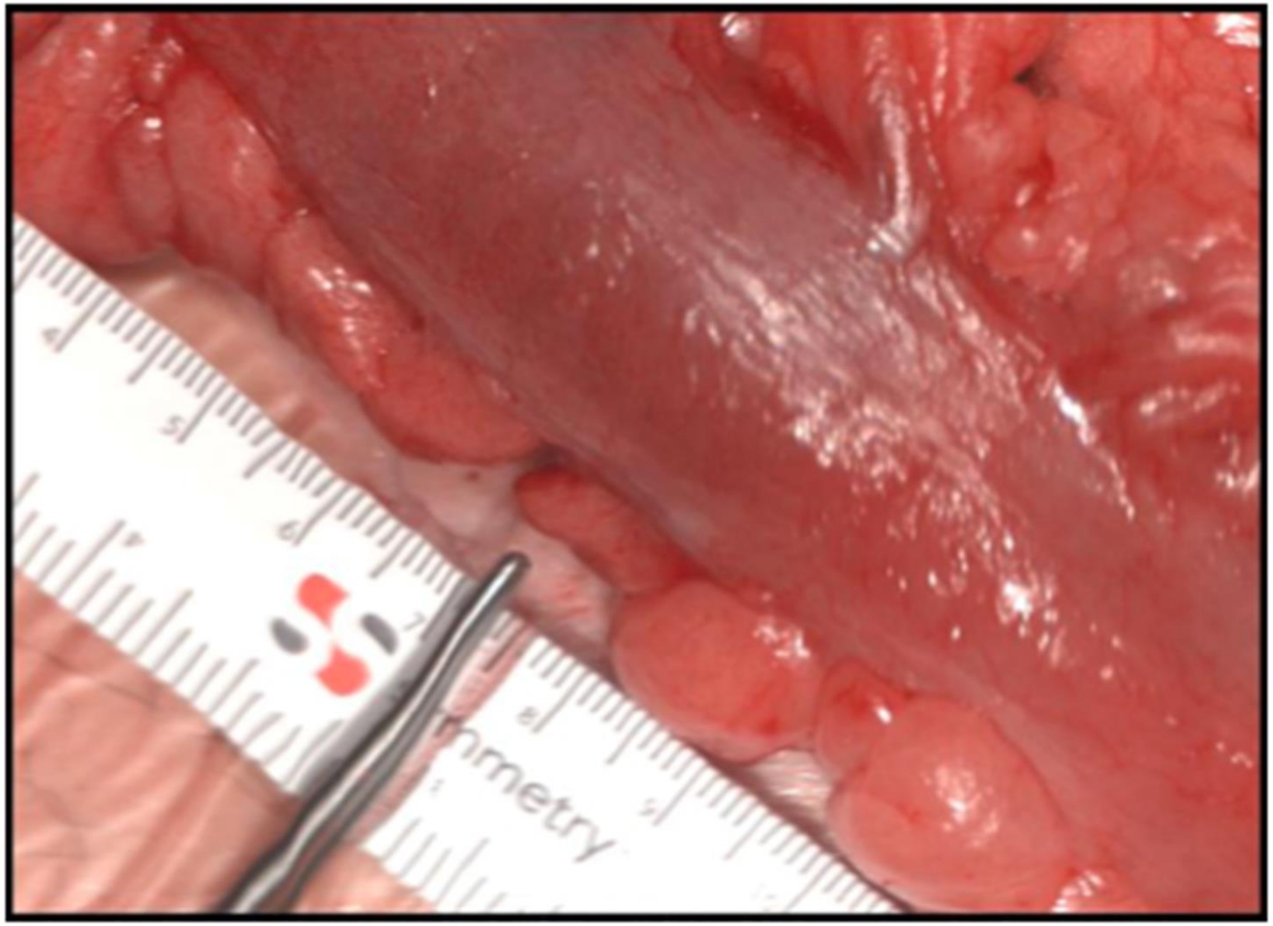
- intraoperative visualization of the surgeon is not objective
- too much resection: perfusion ↑, but bowel probably too short!
- too short resection: perfusion ↓
- optimum transection line!?



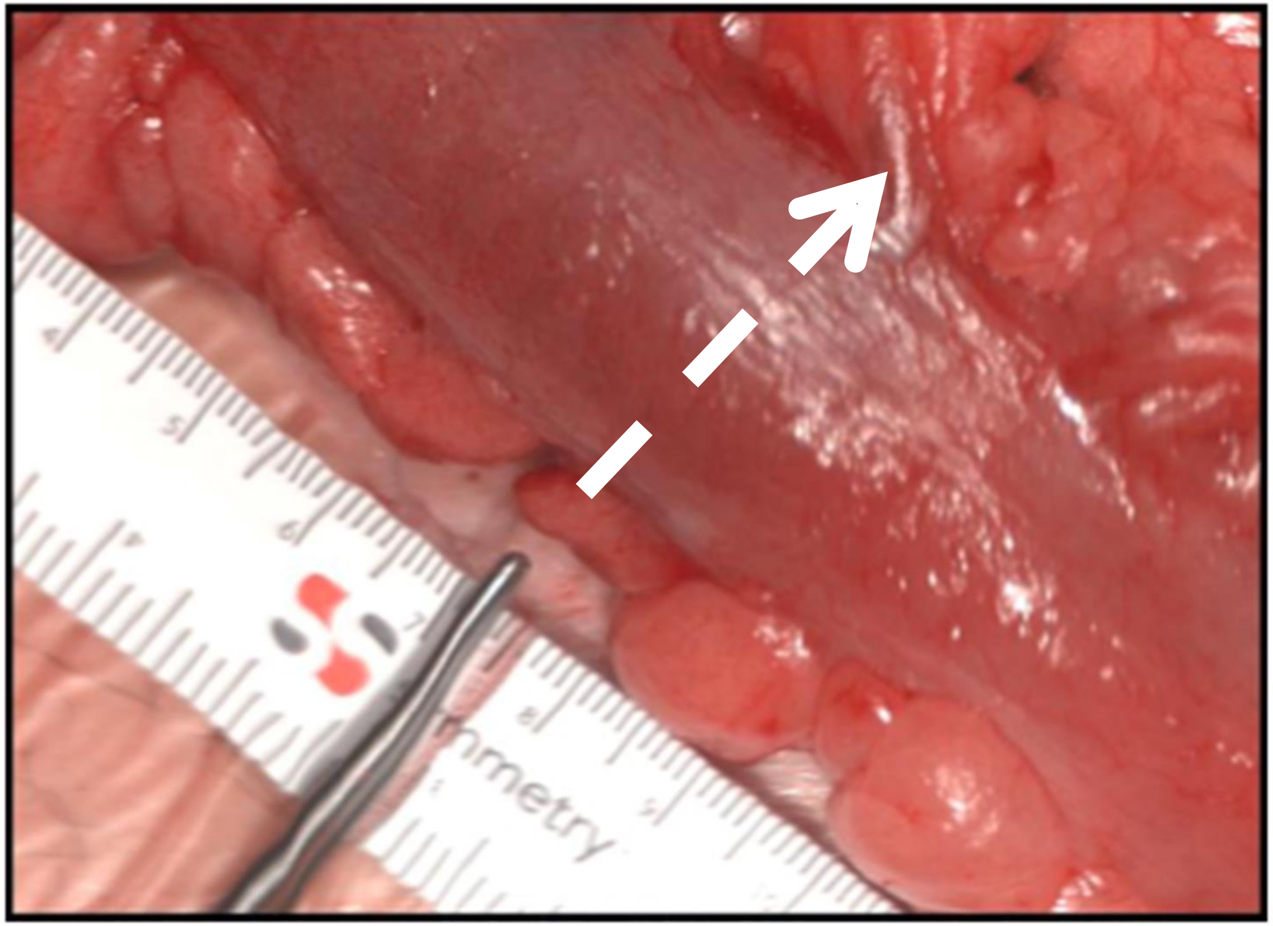
Proximal Resektion Border (PRB):
Where would you transect the descending colon?



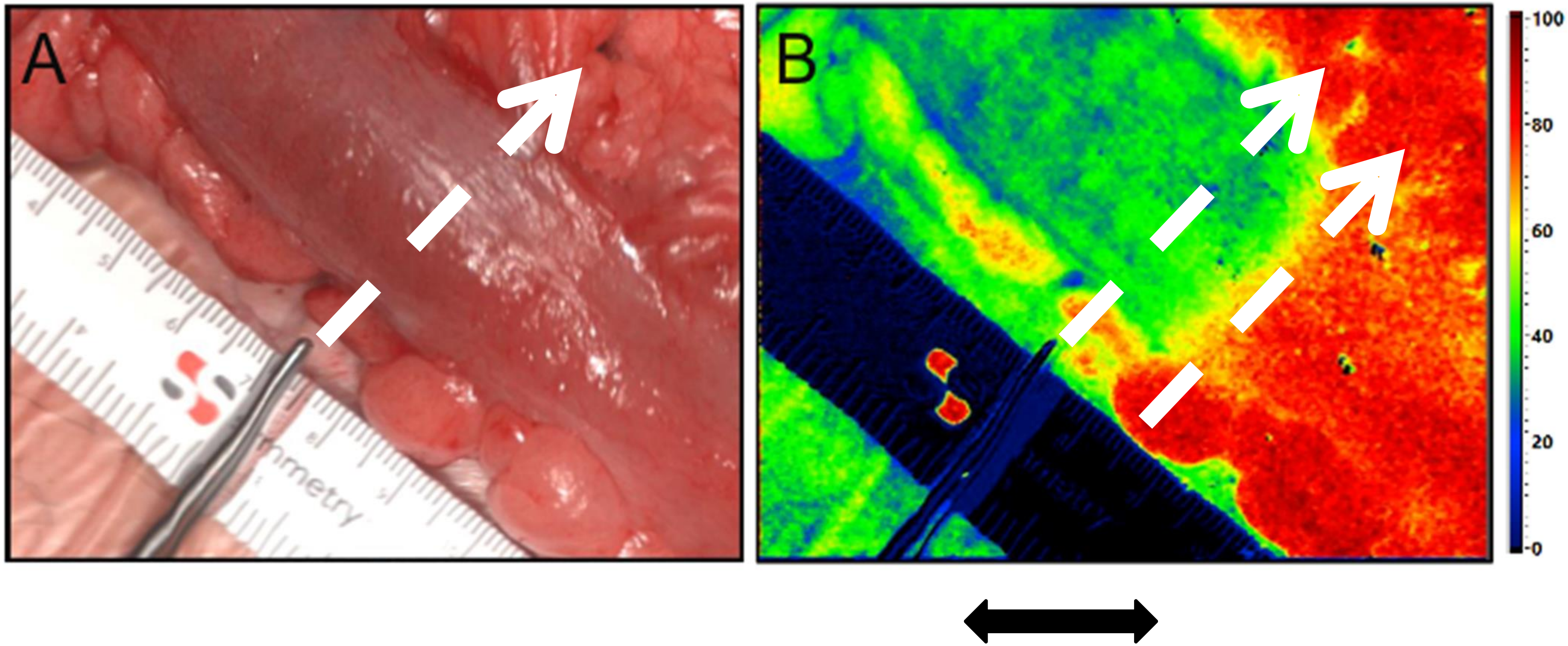
Proximal Resektion Border (PRB):
Where would you transect the descending colon?



Proximal Resektion Border (PRB):
Where would you transect the descending colon?



Comparison with objective HSI-measurement



difference of 2.5 cm

Comparison of subjective vs. objective determination of the transection line (descending colon) I

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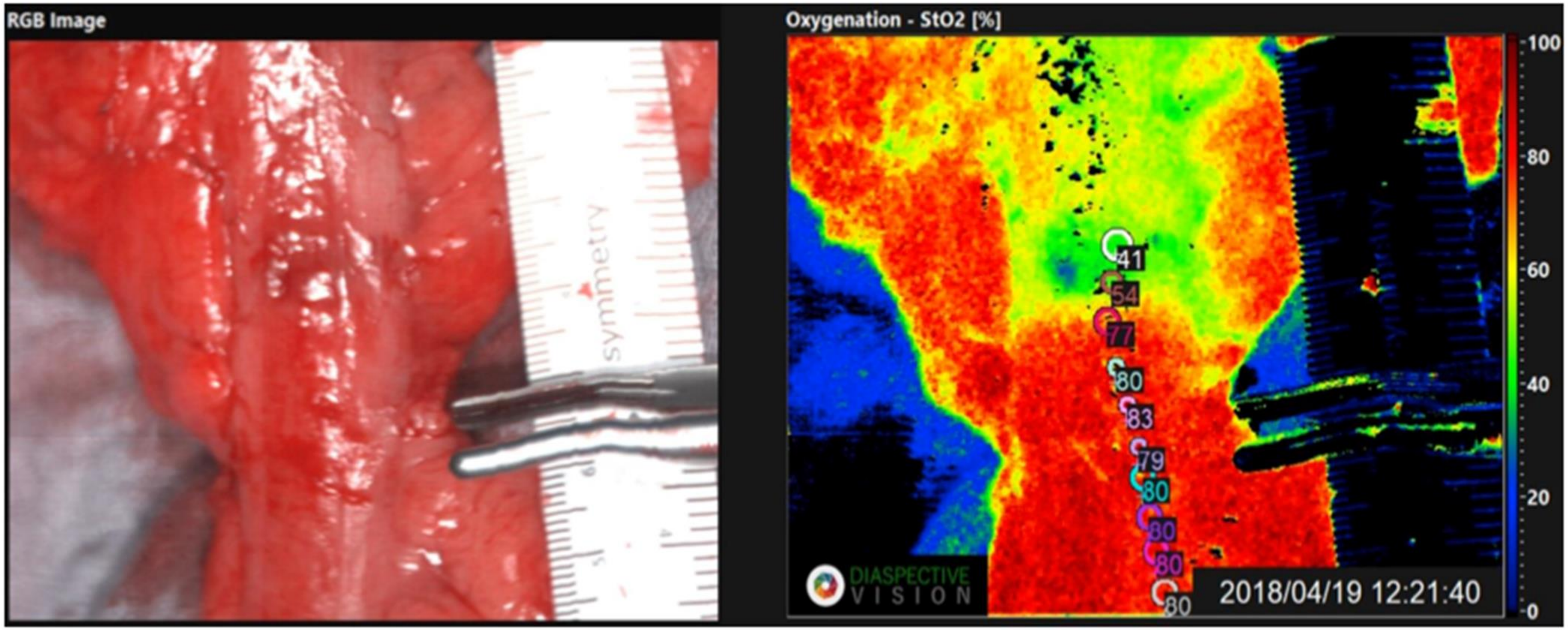
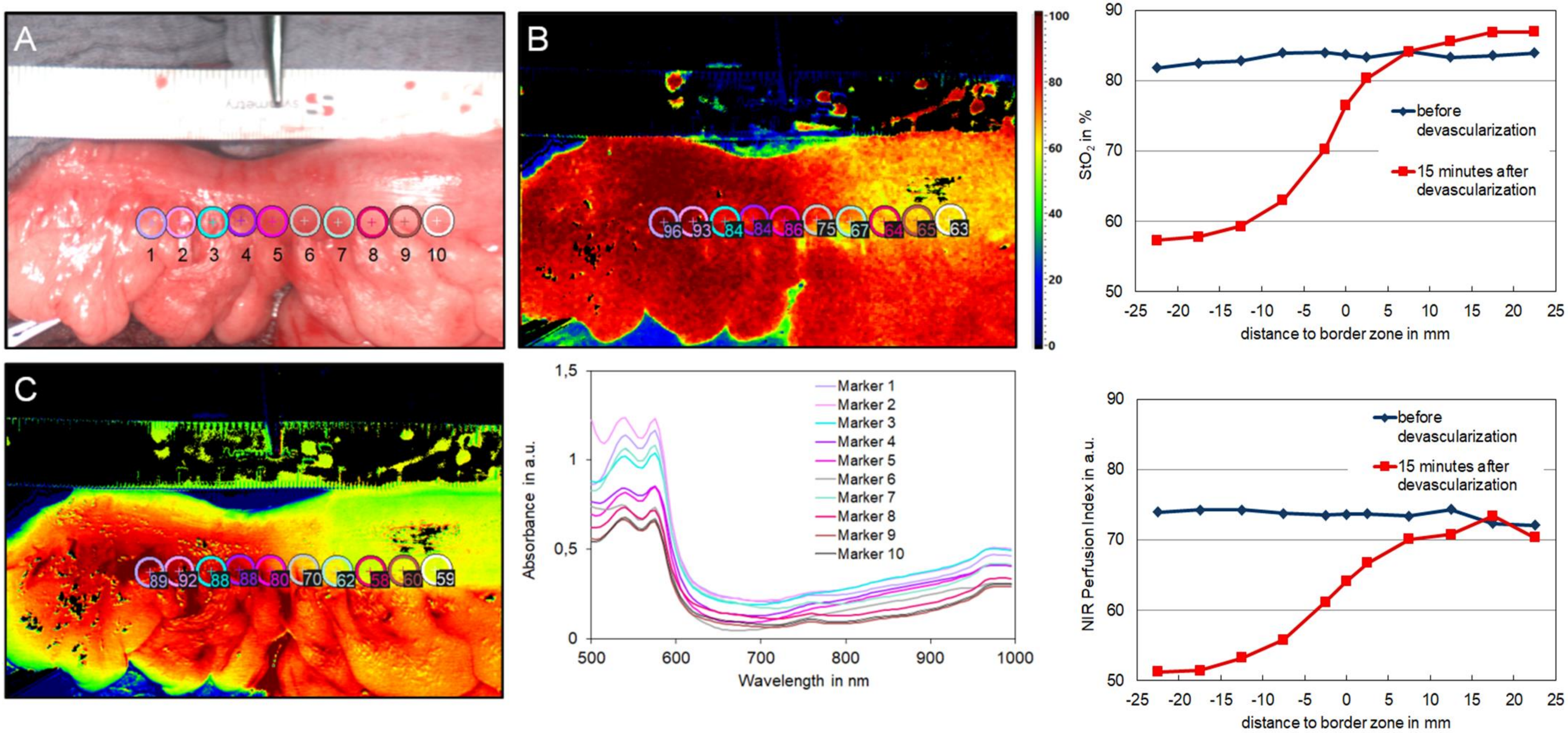


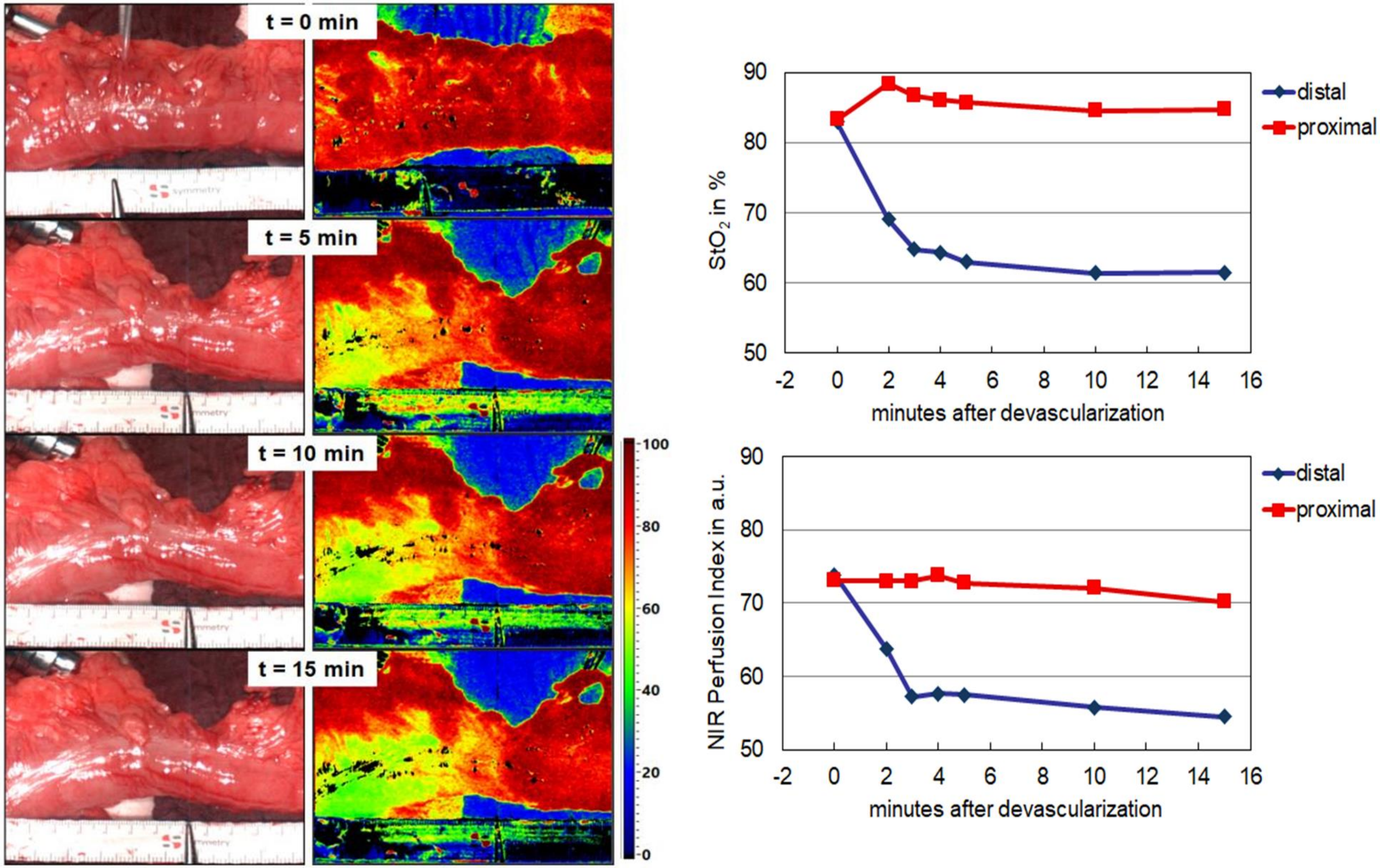
Comparison of subjective vs. objective determination of the transection line (descending colon) II

- before and after devascularization



Jansen-Winkeln B,... Gockel I, *Int J Colorect Dis 2019*

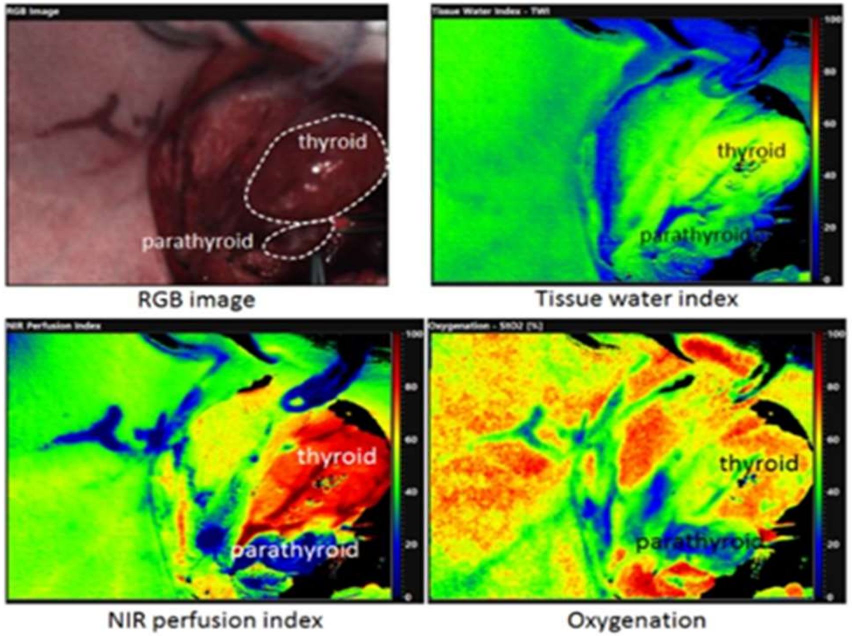
Time course (min after devascularization)



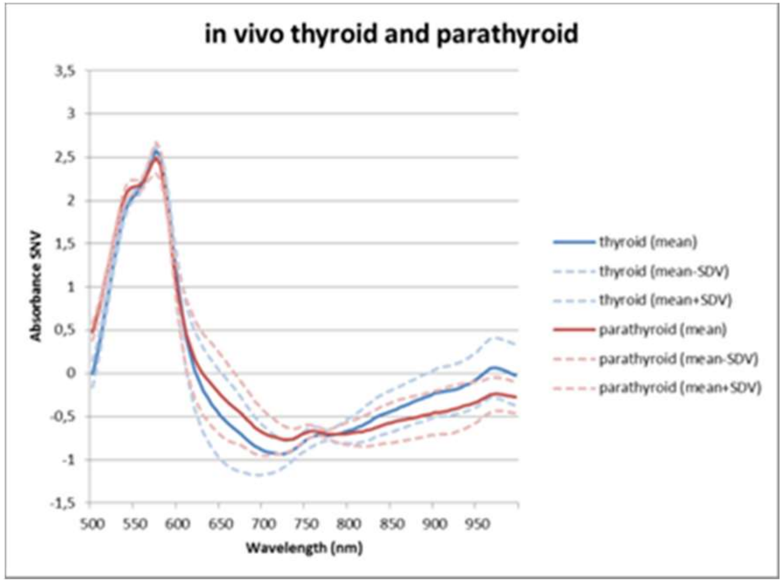
Jansen-Winkeln B,... Gockel I, *Int J Colorect Dis 2019*

Tissue characterization with HSI

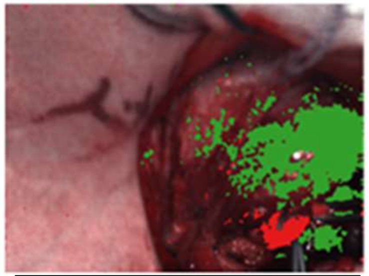
- Differentiation of thyroid and parathyroid *in vivo*



HSI-data



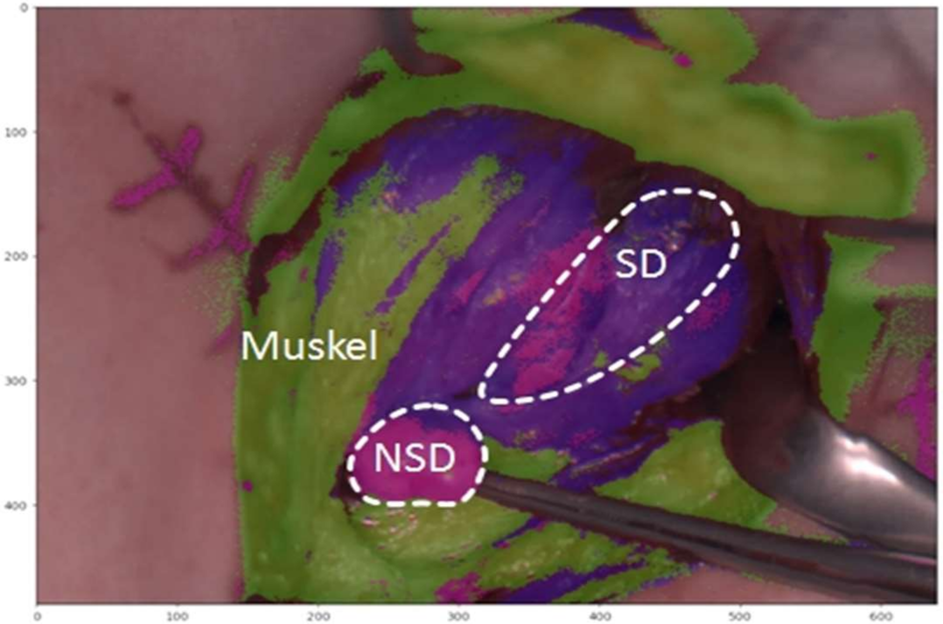
absorption spectra



classification

Tissue-classification with HSI

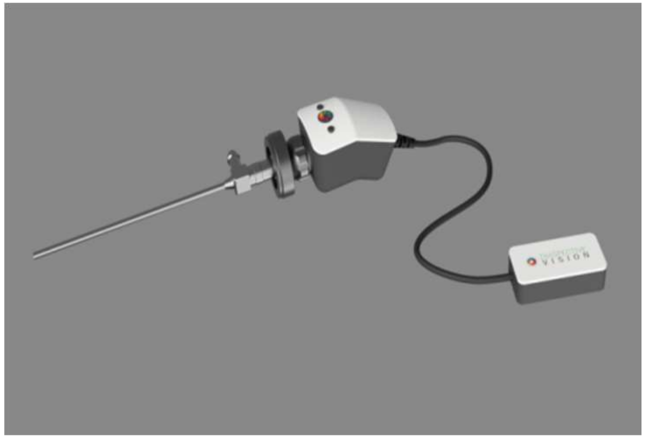
	Schilddrüse	Nebenschilddrüse	Muskel
Genauigkeit (%)	97,10	97,17	98,05
Sensitivität (%)	92,40	90,70	98,47
Spezifizität (%)	98,05	94,74	98,82



Current miniature camera variations

- integrated camera for OR-microscopy

- variants for minimally invasive surgery and endoscopy



Perspectives

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- Combined application of molecular targets of optical imaging, ICG & HSI
- Optimization of surgical results (anastomotic healing)
- Tissue and tumor classifications

Thank you for your attention!

HSI-workshop at the University Hospital of Leipzig

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- 17th May, 2019

Save the Date

<u>in association with:</u>
The German Society of General and Visceral Surgery (DGAV)