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
Development of clinical optical imaging

The human eye


1958 First use of ICG in liver perfusion studies

1998 5-ALA-induced porphyrin fluorescence in malignant gliomas
1998 Introduction of smart activatable probes

2011 Folate–FITC in human ovarian studies

1947 Use of sodium fluorescein and an UV lamp

1994 Blue dye mapping in the sentinel node in breast cancer

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

de Boer E, et al. BJS 2015
Biomarker selection tool and **TArget Selection Criteria (TASC)** and scoring system

**de Boer E, et al. BJS 2015**
Mechanism of action of fluorescent probes

a Non-targeted fluorescent probes  b Targeted fluorescent probes  c Targeted activatable 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

deb E, et al. BJS 2015
ICG = IndoCyanine Green
ICG properties

- **Protein binding** – to plasma proteins quickly, β-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

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

Virtual Reality 3D modeling

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

Augmented Reality overlay in laparoscopic surgery

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

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

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

Hyperspectral Imaging (HSI)

Developed in the 1960's from the

Current applications:
- 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

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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 acquisition methods


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Camera technology

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

Hyperspectral cube

-> spectral signatures can be generated for specific tissues


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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 and relevant components](image-url)
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
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)*

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**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

Hyperspektral-Imaging bei gastrointestinalen Anastomosenen

Jansen-Winkeln B... Gockel I, Chirurg 2018
HSI-application in GI-anastomoses I
HSI-application in GI-anastomoses II

with AL

without AL

a) RGB-Farbbild

b) Gewebe-Hämaglobin-Index THI

STO [%]

Gewebe-Wasser-Index TWI

NIR-Perfusions-Index
Current limitations: Camera size in minimally invasive procedures
Measurements via mini-laparotomy in MIS

Mini-laparotomy: extracorporeal phase
'Key Point': Perfusion of the proximal gastric tube during esophagectomy
Intrathoracic anastomosis

HSI-measurement of the gastric tube

StO₂  
NIR Perfusion  
OHI  
TWI  

10 s  
8 s  
50 cm

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

Oxygenation ($StO_2$)

$StO_{2_{ROI}} = 62\%$

mean ROI in $n=30$ patients
Discrimination of areas with high and low perfusion
HSI-evaluation of the gastric tube

- RGB-image
- Oxygenation (StO$_2$)
- NIR-Perfusion-Index

- Tissue Water-Index
- Tissue Hemoglobin-Index
HSI-evaluation of the gastric tube
before intrathoracic anastomosis
after intrathoracic anastomosis
Tissue oxygenation of the gastric tube was significantly higher in patients with ischemic conditioning (P=0.03)
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

- OFS = Optical Fibre Spectroscopy (SaO$_2$)
- BVF = Blood Volume Fraction

- measurements:
  - 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

(AV-) \( \text{SaO}_2 \)- and BVF-changes in patients with and without ischemic conditioning

<table>
<thead>
<tr>
<th>ischemic conditioning</th>
<th>no (Mean + SD)</th>
<th>yes (Mean + SD)</th>
<th>P-value</th>
<th>no (Mean + SD)</th>
<th>yes (Mean + SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>short gastric vessels</td>
<td>88.6 + 19.7</td>
<td>92.9 + 11.2</td>
<td>0.69</td>
<td>1.10</td>
<td>1.10</td>
<td>0.99</td>
</tr>
<tr>
<td>left gastric artery</td>
<td>74.4 + 26.3</td>
<td>77.4 + 31.0</td>
<td>0.86</td>
<td>0.96</td>
<td>0.96</td>
<td>0.22</td>
</tr>
<tr>
<td>gastric tube formation</td>
<td>67.8 + 37.3</td>
<td>87.8 + 50.6</td>
<td>0.57</td>
<td>1.33</td>
<td>1.33</td>
<td>0.50</td>
</tr>
<tr>
<td>gastric tube transposition</td>
<td>80.7 + 28.6</td>
<td>100.0 + 82.4</td>
<td>0.25</td>
<td>1.56</td>
<td>1.41</td>
<td>0.63</td>
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*relation in % to the basic value

LYSIS-project = laparoscopic hyperspectral system
Determination of the transection margin in colorectal resection with HSI

https://doi.org/10.1007/s00384-019-03250-0

ORIGINAL ARTICLE

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

Boris Jansen-Winkeln¹ • N. Holfert¹ • H. Köhler² • Y. Moulla¹ • J. P. Takoh¹ • S. M. Rabe¹ • M. Mehdorn¹ • M. Barberio¹,³ • C. Chalopin² • T. Neumuth² • I. Gockel¹

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

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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

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## Tissue-classification with HSI

<table>
<thead>
<tr>
<th></th>
<th>Schilddrüse</th>
<th>Nebenschilddrüse</th>
<th>Muskel</th>
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</thead>
<tbody>
<tr>
<td>Genauigkeit (%)</td>
<td>97,10</td>
<td>97,17</td>
<td>98,05</td>
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<tr>
<td>Sensitivität (%)</td>
<td>92,40</td>
<td>90,70</td>
<td>98,47</td>
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<tr>
<td>Spezifizität (%)</td>
<td>98,05</td>
<td>94,74</td>
<td>98,82</td>
</tr>
</tbody>
</table>
Current miniature camera variations

- integrated camera for OR-microscopy

- variants for minimally invasive surgery and endoscopy
Perspectives

- 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

17th May, 2019

Save the Date

in association with:
The German Society of General and Visceral Surgery (DGAV)