Quand l’imagerie optique s’invite au bloc opératoire

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Outline

• Motivations
• Fluorescence imaging
• Endogenous imaging
• What’s next?
• Conclusion
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Surgery: the engineer perspective

1950s

- Few tools available
- Surgery is performed **subjectively**
  - Surgeon relies on his own senses
  - Experience dependent
- Variable outcome
- Recurrence, morbidity, mortality

2000s
Light and tissues

μ_a  |  Absorption
μ_s' |  Scattering
Fluorescence

Red color
Blurring
Molecular Imaging for Surgery

**Exogenous information**
- NIR
- Color-NIR Merge

**Endogenous information**
- Absorption
- Scattering

**Qualitative Contrast Agent Localization**
- Specific (i.e. targeted)
- Non-Specific (i.e. passive)

**Quantitative Endogenous Imaging**
- Hemoglobin $\leftrightarrow$ Oxygen saturation
- Lipids $\leftrightarrow$ Metabolism
- Water $\leftrightarrow$ Hydration
- Scattering $\leftrightarrow$ Subcellular content
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Fluorescence imaging: basics

Contrast agent

Imaging device

Gioux et al., Mol Imaging, 2010; 9: 237-255
Preclinical example

Matsui et al., Surgery 2010
Nguyen et al., J Surg Res 2012
The evolution of imaging devices

Early prototypes

- Miniaturization
- Low cost
- High performance
Fluorescence imaging today

- Devices used on over 1000 patients
- Over 8 commercial devices available
- Relies on already approved dyes (ICG, MB)
- New contrast agents under human trial (10+)

Flap perfusion  Ureters detection  SLN mapping

FIGS: a success?

- Translation performed using advanced imaging systems but poor molecular probes
- Challenges in comparing results

- Progress needed:
  - Invent and translate probes that are specific
  - Standardize measurements
    * Between patients, surgeons and hospitals
    * Repeatable and interpretable
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PARADIGM SHIFT: photons interact within living tissues
Requirements for technology

- Technological needs
  - Real-time
  - Quantitative
  - Wide-field

Real-time

Point spectroscopy

Quantitative

SFDI

CW fluorescence

Wide field
Single Snapshot of Optical Properties (SSOP)

Vervandier et al., Biomedical Optics Express, 2013, 4(12):2938-44.
Validation on Pigs

- Oxygenation imaging on
  - Skin flaps
  - Bowel
  - Liver

- Comparison with gold standard: Vioptix T.Ox
First-in-human Pilot Study

Gioux et al. JBO. 2011. 26:086015.


21
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Real-time quantitative fluorescence imaging

• Issue: Fluorescence imaging is qualitative

• Need: Quantitative fluorescence imaging

• Objective: use endogenous imaging to correct for tissue properties
Real-time quantitative fluorescence imaging

Valdes et al., Biomedical Optics Express, 2017; 8(8): 3597-605
Real-time quantitative fluorescence imaging

Valdes et al., Biomedical Optics Express, 2017; 8(8): 3597-605
Endoscopic real-time quantitative imaging

• Issue: Over 50% of all surgeries are minimally invasive and lack feedback

• Need: Providing objective feedback in endoscopes

• Objective: Adapt SSOP technology
Endoscopic real-time quantitative imaging
Endoscopic **real-time quantitative imaging**

- Endoscope serializable + sterile drape
- Undergoing clinical translation with IHU
Real-time *multispectral* quantitative imaging

- **Issue:** Optical properties are not enough to make decisions

- **Need:** Provide interpretable images

- **Objective:** Acquire & process multiple wavelengths in real-time
Spatio-temporal modulation of light

Time

Space

\[ \lambda_1 \]

\[ \lambda_n \]

Projector

Camera

Intensity

Time

DFT processing

SSOP processing

\[ \mu_a(\lambda_1) \]

\[ \mu_a(\lambda_n) \]

\[ \mu_s(\lambda_1) \]

\[ \mu_s(\lambda_n) \]
Real-time multispectral quantitative imaging

$\lambda = 665\text{nm}$

$\mu_a [\text{mm}^{-1}]$  
$\mu_s' [\text{mm}^{-1}]$

$\lambda = 860\text{nm}$

$\mu_a [\text{mm}^{-1}]$  
$\mu_s' [\text{mm}^{-1}]$
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Making Sense in Surgery™

• To help surgeons’ decision-making
• By creating new senses (i.e. interpretable information)

• Optical imaging for surgery
  – Real-time, wide-field, quantitative
  – Safe, inexpensive

• Currently transitioning from proof-of-concept to clinical trials
  – Perfusion assessment (e.g. PAD, anastomosis)
  – Transplant status assessment (e.g. liver, flaps)
  – *In situ* diagnosis (e.g. CRC, SLN mapping)
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