Panel 4 - Beyond the Visible: The Future of Endoscopy – Computer Vision Explained
Professional Education Information

Target Audience
This educational activity is developed to meet the needs of surgical gynecologists in practice and in training, as well as other healthcare professionals in the field of gynecology.

Accreditation
AAGL is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

The AAGL designates this live activity for a maximum of 1.0 AMA PRA Category 1 Credit(s)™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

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Table of Contents
Session Program (Description and Learning Objectives) ................................................................. 1
Disclosure .............................................................................................................................................. 2

Intraoperative Hyperspectral Label-Free Imaging: From System Design to First-in-Patient Translation
T. Vercauteren ..................................................................................................................................... 3

Image Guided Surgery: From Technical Innovation to Machine Learning and Computer Vision Revolution
N. Bourdel .............................................................................................................................................. 8

Cultural and Linguistic Competency .................................................................................................. 14
Panel 4-Beyond the Visible: The Future of Endoscopy – Computer Vision Explained

Chair: Michel Canis

Faculty: Nicolas Bourdel, Tom Vercauteren

The endoscopic revolution was based on several technical innovations, mainly an improved vision of the surgical field. As we move to the future, our surgical vision will be improved using numerical images, augmented reality and machine learning computer vision as the cornerstone of this revolution. Although these tools are already applicable in clinical practice, surgeons will have to collaborate with computer scientists to design the surgical technologies of the future. These technologies, based on software, will allow us to identify structures which are not currently visible. This will facilitate the identification of vulnerable structures, such as ureters, diseases such as myomas and endometriosis, and will revolutionize our surgical practice.

Learning Objectives: At the conclusion of this course, the participant should be able to: 1) Explain the basic principles of: 1) Deep learning in medical image analysis; 2) hyperspectral label-free imaging; 3) machine learning algorithm for surgery; 4) augmented reality and 5) computer vision.

COURSE OUTLINE

3:15 pm Welcome, Introductions and Course Objectives M. Canis

3:20 pm Intraoperative Hyperspectral Label-Free Imaging: From System Design to First-in-Patient Translation T. Vercauteren

3:45 pm Image Guided Surgery: From Technical Innovation to Machine Learning and Computer Vision Revolution N. Bourdel

4:05 pm Faculty Discussion/Questions and Answers

4:15 pm Adjourn
PLANNER DISCLOSURE
The following members of AAGL have been involved in the educational planning of this workshop (listed in alphabetical order by last name).

Linda J. Bell, Admin Support, AAGL*
Linda D. Bradley, MD, Medical Director, AAGL*
Erin T. Carey, MD, MSCR
Honorarium: Teleflex Medical, MedIQ
Mark W. Dassel, MD
Contracted Research: Myovant Sciences
Linda Michels, Executive Director, AAGL*
Vadim Morozov, MD
Speaker: AbbVie
Consultant: Medtronic, Lumenis
Erinn M. Myers, MD
Speakers Bureau: Laborie Medical Technologies, Teleflex Medical
Other: Unrestricted educational grant to support NC FPMRS Fellow Cadaver Lab: Boston Scientific Corp. Inc.
Amy Park, MD
Speaker: Allergan
Nancy Williams, COO, CME Consultants*
Harold Y. Wu, MD*
Michel Canis, MD, PhD*

FACULTY DISCLOSURE
The following have agreed to provide verbal disclosure of their relationships prior to their presentations. They have also agreed to support their presentations and clinical recommendations with the “best available evidence” from medical literature (in alphabetical order by last name).

Nicolas Bourdel, MD, PhD*
Tom Vercauteren, PhD
Stock Ownership: Mauna Kea Technologies
Contracted Research: Moon Surgical, Medtronic

Content Reviewers have nothing to disclose.

Asterisk (*) denotes no financial relationships to disclose.

All relevant financial relationships noted have been mitigated.

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Speakers Bureau: Covidien

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Speakers Bureau: Medtronic, CooperSurgical, Merck & Co., AstraZeneca, Roche
Linda Michels, Executive Director, AAGL*
Intraoperative Hyperspectral Label-Free Imaging: From System Design to First-in-Patient Translation

Tom Vercauteren, PhD
Professor of Interventional Image Computing, King’s College London
Co-founder and Chief Scientific Officer (CSO), Hypervision Surgical Ltd

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Disclosures

• Co-founder and shareholder of Hypervision Surgical Ltd
• Shareholder of Mauna Kea Technologies
• Medtronic / Royal Academy of Engineering Research Chair in Machine Learning for Computer-assisted Surgery
• Recipient of research funding from Moon Surgical, Intel, NIHR, Wellcome Trust, Royal Academy of Engineering, European Commission, EPSRC

"As surgeons, we cannot always reliably differentiate healthy from tumour tissue during surgery”
Jonathan Shapey, Consultant Neurosurgeon
at King’s College Hospital and Hypervision Surgical Co-founder

30% complication rate
30% significant residual tumour
$1B US overspending

30% of brain surgery leaves tumour behind

Contrast agent needed
Subjective margin assessment
No measure on brain perfusion

Anastomotic leakage occurs up to 8-15% post colorectal surgery

Contrast agent needed
Time-dependent assessment
Non-quantitative perfusion assessment

Broad need for improved surgical tissue characterisation

Blood Oxygenation
• 2,400 UK episodes/year
• 12% mortality
• 25% complications

Brain vascular cancer

Brain cancer
• 5,000 UK episodes/year
• 300k US-EU patients/year
• 30% repeat surgery
• 20% complications

Breast cancer
• 60,000 UK cases/year
• 600k US-EU cases/year

Colorectal cancer
• 43,000 UK cases/year
• 500k US-EU diagnoses/year
• 8-15% anastomotic leaks

Endometrial cancer
• 11,000 UK cases/year
• 200k US-EU cases/year
• 15% recurrence
Can we do better with visible light and AI?

Are we all (somewhat) colour blind?

Metamerism

Metamerism: Same colour under given light source but different spectrum

Hyperspectral imaging: Colour imaging beyond RGB

First generation HSI systems used during surgery

Quantitative perfusion assessment during colorectal surgery

Tumour/tissue mapping during neurosurgery
### Functional requirements mapping for surgery: Overview

<table>
<thead>
<tr>
<th>Category</th>
<th>Functional requirement</th>
<th>Gen 1 HSI</th>
<th>Fluorescence</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Surgical safety &amp; sterility</td>
<td>Safe and sterile intraoperative use throughout the surgical procedure</td>
<td>✓</td>
</tr>
<tr>
<td>F2</td>
<td>Technical safety</td>
<td>Compliant with electrical and light source safety standards</td>
<td>✓</td>
</tr>
<tr>
<td>F3</td>
<td>Lighting</td>
<td>Illumination must not impede surgical workflow</td>
<td>✓</td>
</tr>
<tr>
<td>F4</td>
<td>Maintenance</td>
<td>Maintenance &amp; cleaning compliant with standard clinical practice</td>
<td>✓</td>
</tr>
<tr>
<td>F5</td>
<td>Device handling</td>
<td>handheld device easily manoeuvrable without an assistant; securely and easily mountable in the surgical field</td>
<td>✓</td>
</tr>
<tr>
<td>F6</td>
<td>Anatomical coverage</td>
<td>Large field of view (FOV) compatible with the surgical action</td>
<td>✓</td>
</tr>
<tr>
<td>F7</td>
<td>Anatomical feature</td>
<td>Extraction of critical functional &amp; semantic features to increase surgical precision and patient safety</td>
<td>✓ partialy</td>
</tr>
<tr>
<td>F8</td>
<td>Anatomical detail</td>
<td>Ability to differentiate anatomical tissues with high anatomical detail (e.g. Full HD)</td>
<td>✓</td>
</tr>
<tr>
<td>F9</td>
<td>Imaging rate</td>
<td>Video-rate imaging for instant surgeon feedback</td>
<td>✓</td>
</tr>
<tr>
<td>F10</td>
<td>Visualisation</td>
<td>Intuitive and accurate visualisation of extracted information</td>
<td>✓</td>
</tr>
</tbody>
</table>

#### Real-time HSI through with snapshot mosaic sensors and AI

- **Image courtesy of IMEC**
- **Brain data courtesy Fabelo et al, IEEE Access 2019**
- **First in-patient study demonstrated feasibility**
- **Ethically-approved clinical study in Zurich, Switzerland**
- **"Smooth handling of the device ensured seamless surgical integration" Jonathan Shapey, Consultant Neurosurgeon and Hypervision Surgical co-founder**
- **Ex vivo supporting results**
- **Deep learning for snapshot HSI demosaicking**

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Ebner et al, J Phys D, 2021

Li et al, CMBBEVE, 2021

Shapey et al, SPIE BiOS, 2020

Data courtesy of IMEC
Exemplar results (synthetic) of AI processing: RGB display

User survey

- 12 clinical experts
- Subjective assessment of image quality
- Likert scale rating

Joint AI-based reconstruction and perfusion estimation

Opportunities and next steps for AI-enabled IHSI

Seamless integration into surgical workflow
- AI-based intraoperative HSI (IHSI) super-resolution
- Real-time quantitative AI imaging:
  - Blood perfusion
  - Tissue boundaries (tumour type, normal brain, nerves, blood vessels)
- Evaluated in first-in-patient studies and further clinical studies underway

Conclusion

- Intelligent Vision can significantly impact across surgical specialties
  - Examples include:
    - Blood perfusion
    - Tissue differentiation
    - Brain surgery
    - Blood vessel
    - Tumour
    - Colorectal surgery
    - Anastomotic leaks
    - Breast surgery
    - Breast flaps
    - Tumour
    - Robotic surgery
    - General robotic
    - Urology & gynaecology

Intraoperative Hyperspectral Label-Free Imaging: From System Design to First-in-Patient Translation

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Professor of Interventional Image Computing, King’s College London
Co-founder and Chief Scientific Officer (CSO), Hypervision Surgical Ltd

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Thank you!
References


Vercauteren – AAGL 2021 – iHSI

26

Page 7
Image Guided Surgery: From Technical Innovation to Machine Learning and Computer Vision Revolution

Nicolas Bourdel MD, PhD, Professor,
Surgical Gynecology CHU Clermont Ferrand, Université Clermont Auvergne, France
Adrien Bartoli, Pauline Chauvet, Michel Carla, Claire Figuier, Sabrina Madad, Callyane Seve

Disclosure
○ CEO, Cofunder:

The synergy between interdisciplinary collaboration and convergence of multiple technologies ... providing extensive visual information layers ... and making them intuitive, upgrading existing surgical skills and forging new ones. Due to its comprehensive mindset ... a breakthrough transformation emerges to enforce state-of-the-art procedures and others, thereby achieving precision.

Technical Innovation
new or improved product or process whose technological characteristics are significantly different from before

Use of indocyanine green in endometriosis surgery
Indocyanine green is a dye (fluorescent dye) administered to enhance visualization of blood vessels.

Image guided surgery
• Computer-assisted surgery
• computer-aided surgery
• computer-assisted intervention
• digital surgery
The synergy between interdisciplinary collaboration and convergence of multiple technologies ... providing extensive visual information layers ... and making them intuitive, upgrading existing surgical skills and forging new ones. Due to its comprehensive mindset ... a breakthrough transformation emerges to enforce state-of-the-art procedures and others, thereby achieving precision.
Machine Learning
Computer algorithm that can improve automatically through experience and by the use of data.

Deep Learning
Part of machine learning methods based on artificial neural networks

Machine Learning

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<td>39</td>
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</tr>
<tr>
<td>40.9</td>
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</tr>
</tbody>
</table>

Prediction

\[ Y = ax + b \]

Examples...

Carcinomatosis?
Endometriosis?
Stage?
Extension?

Complex data

Artificial Neuronal network
What is a artificial neuron?
A mathematical function!

What we need?

X1
X2
X3
...
**Artificial Neuron**

\[ p_1 x_1 + p_2 x_2 + p_3 x_3 \]

- If \( > T \) \( \rightarrow Y = 1 \)
- If \( < T \) \( \rightarrow Y = 0 \)

**Biological Neuron**

**Neuronal Network**

**Learning Phase**

- Input \( X \) → Output \( Y \)

**Prediction Phase**

- New inputs \( X \) → Prediction \( Y \)

**Machine Learning/Deep Learning in Surgery**

- 400 images
- 4000 images

**AI Guided Surgery**

Example of Bleeding detection

100,000 images

**Computer Vision**

- The scientific field that deals with the computational inference of information from images
- Strong connections with mathematics and computer science

Intraoperative 3D reconstruction: computer vision

Augmented Reality Ingredients for Assisted Gynecological Surgery

A real image of a human uterus
A 3D uterus model from pre-operative MRI

Image augmented with uterus model

Augmented Reality

The Augmented Reality Process: Registration?

Computer Vision-based Registration

Anatomical landmarks Contours Natural texture Biomechanics Stereo 3D Reconstruction
Deep Learning Registration

Deformation: example of the liver

Real time augmented reality!

Guidance tools

Deformation: example of the liver
CULTURAL AND LINGUISTIC COMPETENCY

Assembly Bill 1195 was signed into law on July 1, 2006 requiring local CME providers, such as the AAGL, to assist in enhancing the cultural and linguistic competency of California’s physicians (researchers and doctors without patient contact are exempt). This mandate follows the federal Civil Rights Act of 1964, Executive Order 13166 (2000) and the Dymally-Alatorre Bilingual Services Act (1973), all of which recognize, as confirmed by the US Census Bureau, that substantial numbers of patients possess limited English proficiency (LEP). It is the intent of the Legislature to encourage physicians and surgeons, continuing medical education providers located in California, and the Accreditation Council for Continuing Medical Education to meet the cultural and linguistic concerns of a diverse patient population through appropriate professional development.

Linguistic Competence: Providing readily available, culturally appropriate oral and written language services to limited English proficiency (LEP) members through such means as bilingual/bicultural staff, trained medical interpreters, and qualified translators.

Cultural Competence: A set of congruent behaviors, attitudes, and policies that come together in a system or agency or among professionals that enables effective interactions in a cross-cultural framework.1

Cultural and Linguistic Competence: The ability of health care providers and health care organizations to understand and respond effectively to the cultural and linguistic needs brought by the patient to the health care encounter.

Cultural competence requires organizations and their personnel to:
- Value diversity.
- Assess themselves.
- Manage the dynamics of difference.
- Acquire and institutionalize cultural knowledge.
- Adapt to diversity and the cultural contexts of individuals and communities served.

California Business & Professions Code §2190.1(c)(3) states that associations that accredit continuing medical education courses shall develop standards before July 1, 2006, for compliance with the cultural competency requirements. The associations may update these standards, as needed, in conjunction with an advisory group that has expertise in cultural and linguistic competency issues. Cultural competency means a set of integrated attitudes, knowledge, and skills that enables a health care professional or organization to care effectively for patients from diverse cultures, groups, and communities. At a minimum, cultural competency is recommended to include the following: (A) Applying linguistic skills to communicate effectively with the target population. (B) Utilizing cultural information to establish therapeutic relationships. (C) Eliciting and incorporating pertinent cultural data in diagnosis and treatment. (D) Understanding and applying cultural and ethnic data to the process of clinical care, including, as appropriate, information pertinent to the appropriate treatment of, and provision of care to, the lesbian, gay, bisexual, transgender, and intersex communities.

Title VI of the Civil Rights Act of 1964 prohibits recipients of federal financial assistance from discriminating against or otherwise excluding individuals on the basis of race, color, or national origin in any of their activities. In 1974, the US Supreme Court recognized LEP individuals as potential victims of national origin discrimination. In all situations, federal agencies are required to assess the number or proportion of LEP individuals in the eligible service population, the frequency with which they come into contact with the program, the importance of the services, and the resources available to the recipient, including the mix of oral and written language services. Additional details may be found in the Department of Justice Policy Guidance Document: Enforcement of Title VI of the Civil Rights Act of 1964 http://www.usdoj.gov/crt/cor/pubs.htm.

Executive Order 13166,”Improving Access to Services for Persons with Limited English Proficiency”, signed by the President on August 11, 2000 http://www.usdoj.gov/crt/cor/13166.htm was the genesis of the Guidance Document mentioned above. The Executive Order requires all federal agencies, including those which provide federal financial assistance, to examine the services they provide, identify any need for services to LEP individuals, and develop and implement a system to provide those services so LEP persons can have meaningful access.

Dymally-Alatorre Bilingual Services Act (Assembly Bill 305) requires that state agencies that serve a substantial number of non-English-speaking people employ a sufficient amount of bilingual persons in order to provide certain information and render certain services in a language other than English.