Use of AI in Image-Guided Minimally Invasive Therapy: *concepts*, *benefits* & *challenges*

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MIMESIS team @ inria

MLMS team @ ICube – University of Strasbourg

18 - 19 JUIN
CONGRÈS 2025
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L'INTELLIGENCE ARTIFICIELLE
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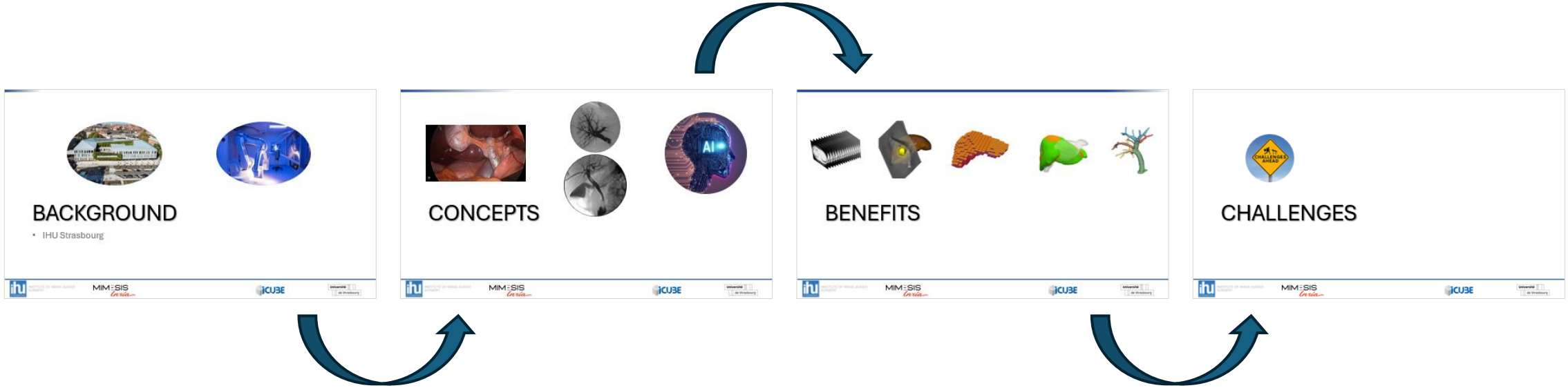
Our path today: from Foundations to Frontiers



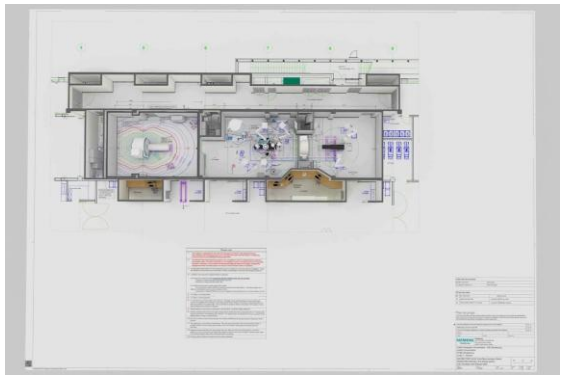
BACKGROUND

- IHU Strasbourg

Institute of Image-Guided Surgery

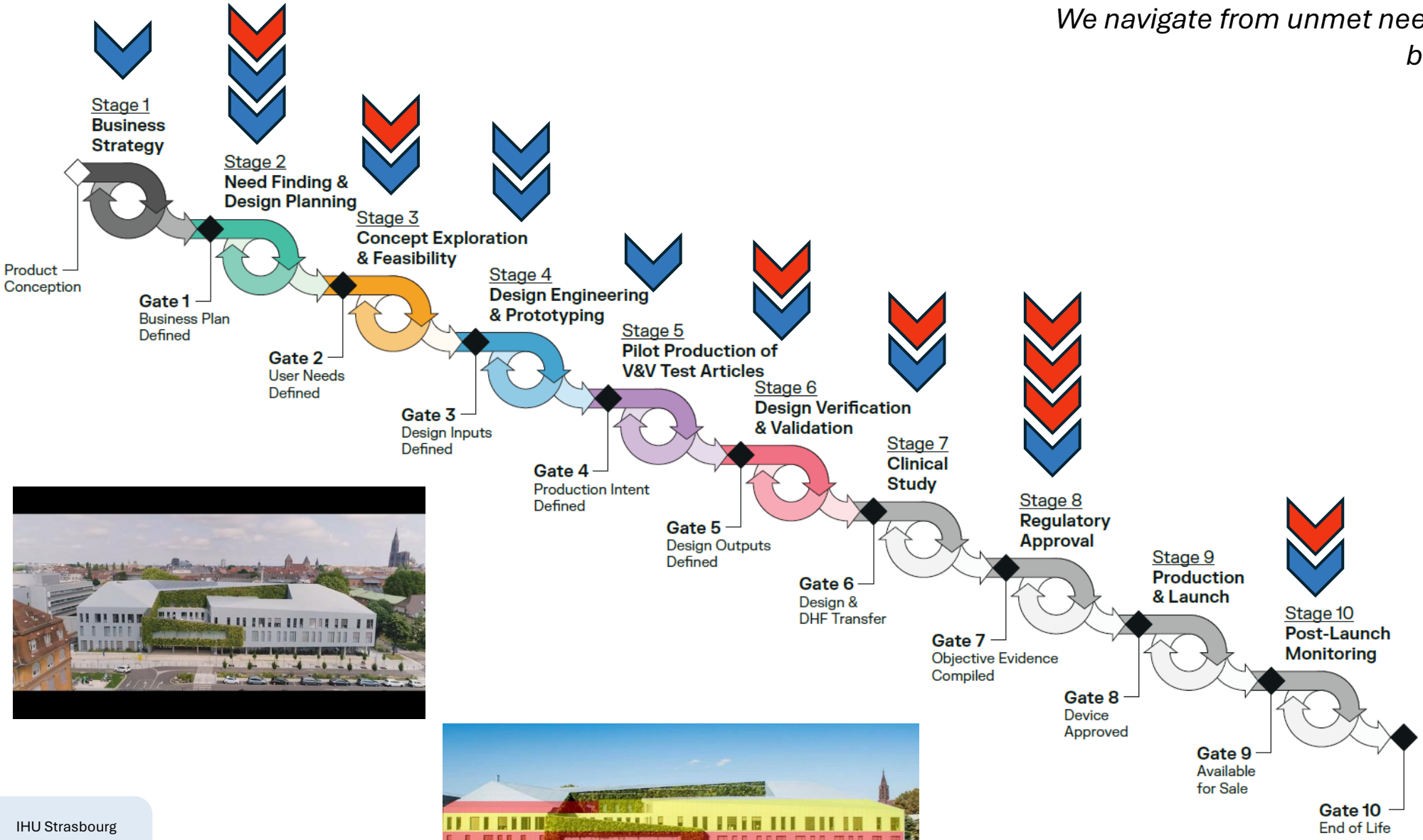






- **Mission**:
  - *Accelerating clinical translation of disruptive technologies to deliver real-world, validated solutions in image-guided therapies*.
- **Infrastructure**:
  - State-of-the-art hybrid operating rooms (experimental, clinical)
  - Advanced prototyping labs
  - Integrated, in-house multidisciplinary expertise
- **Research Focus**:
  - Digital Technologies (AI, XR, Robotics)
  - Advanced medical imaging
  - Therapeutic Modalities (Energy-based)
- **Approach**:
  - Collaborative, clinically anchored, multidisciplinary innovation

We navigate from unmet need to regulatory clearance, bridging translational gaps.



Innovation Unit

↓

Preclinical & Experimental Research Unit

↓

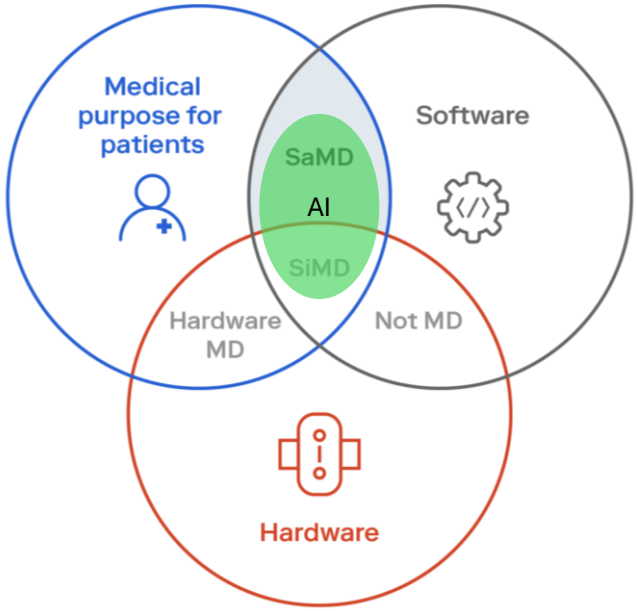
Clinical Research Unit

IHU Strasbourg

Partners / Sponsors

sources: Delve

preoperative → perioperative → intraoperative → postoperative → post-discharge



intraoperative environment

Decision-Making & Cognitive Constraints

- **Real-time decision support:** High-stakes decisions must be made instantly and accurately.
- **Cognitive load:** Operators manage complex, simultaneous stimuli and tasks.
- **Immediacy of action:** Delays in insight or navigation/guidance can directly impact patient outcomes (adverse events / complications).

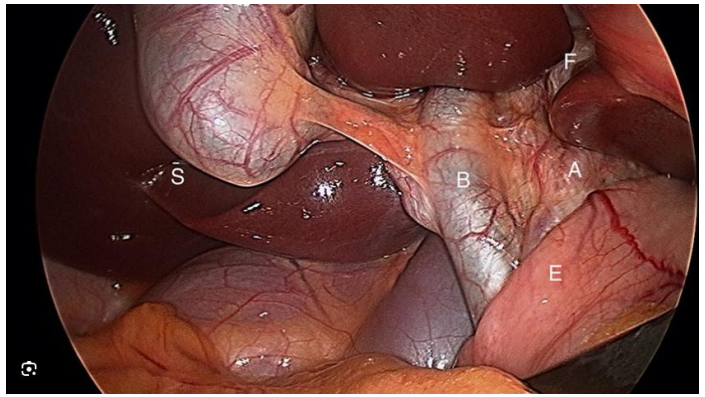
Procedural & Environmental Complexity

- **Dynamic environment:** Constantly evolving anatomy, instrumentation, and tissue response.
- **Constrained physical space:** Limited room for additional equipment; shared access points.
- **Ergonomic and spatial limitations:** Devices must adapt to tight layouts without hindering workflow.

Human Factors & Variability

- **Team dynamics and coordination:** Multidisciplinary, fluid team interactions under time pressure.
- **High inter-operator variability:** Differences in technique, decision pathways, and tool preferences

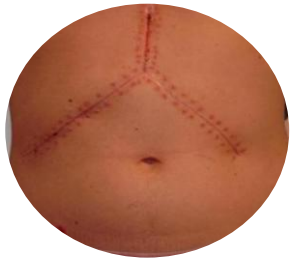
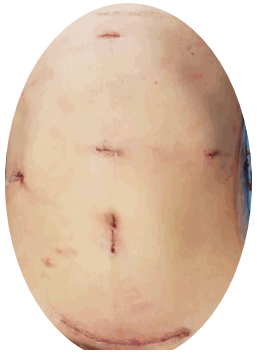
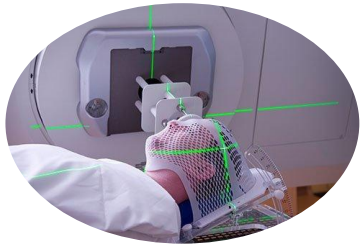
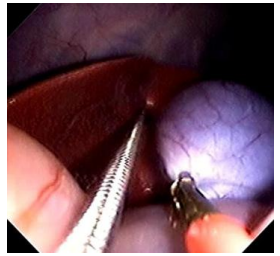
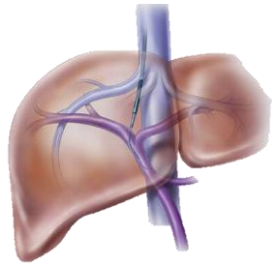
sources: Rangle



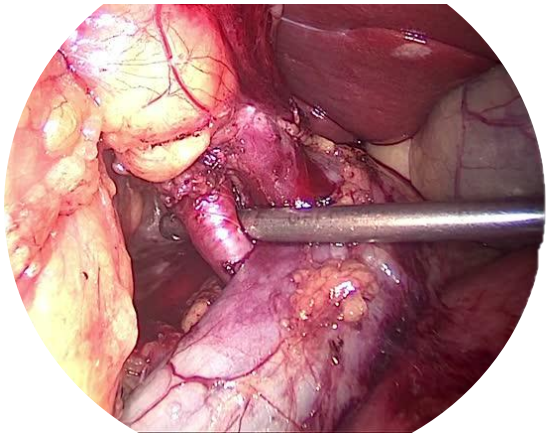
CONCEPTS

↑ Image-dependence

↑ Invasiveness

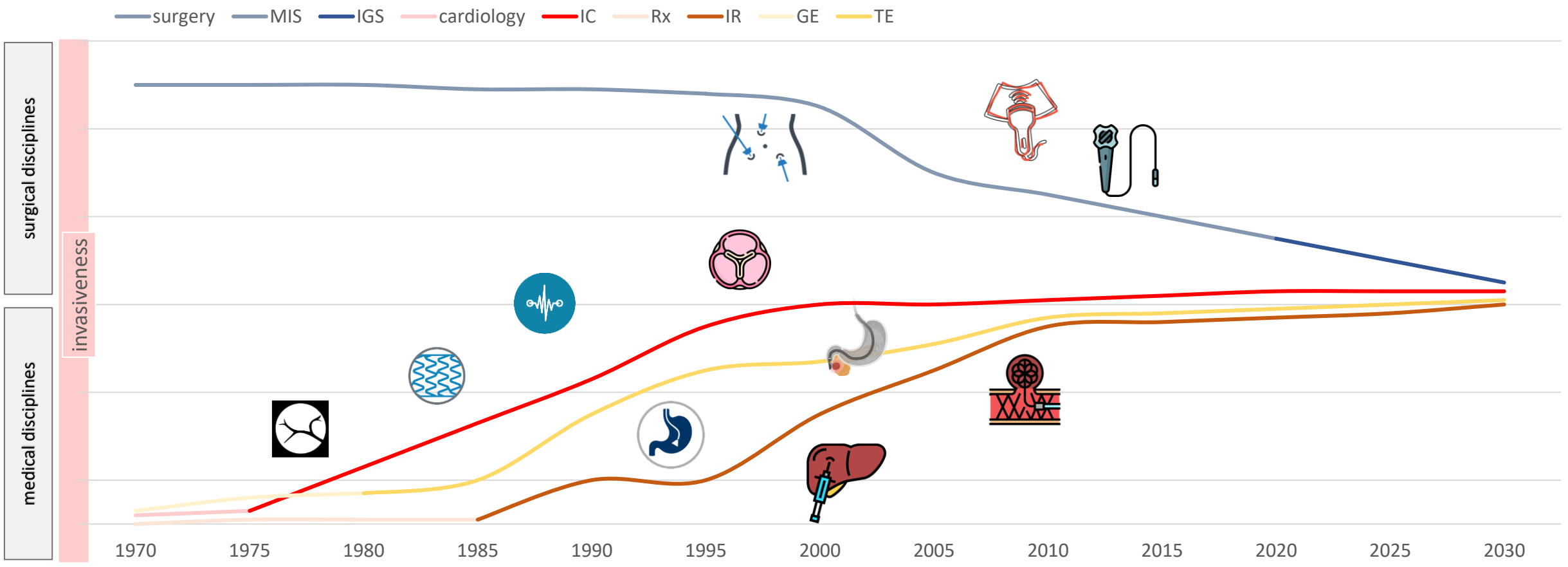
open surgery	lap surgery	NOTES	needle-based	endovascular	noninvasive
					
					

Multimodal Imaging – Foundation for AI



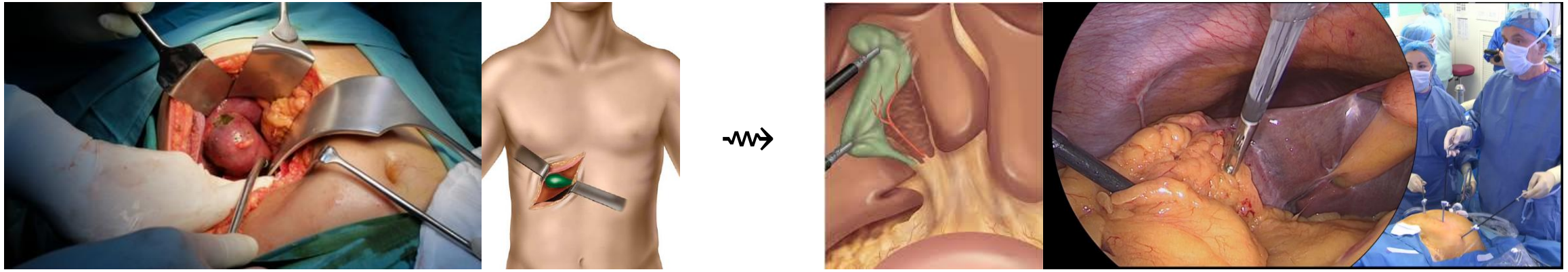
MULTIDISCIPLINARY CONVERGENCE

Blurring Lines Across Specialties



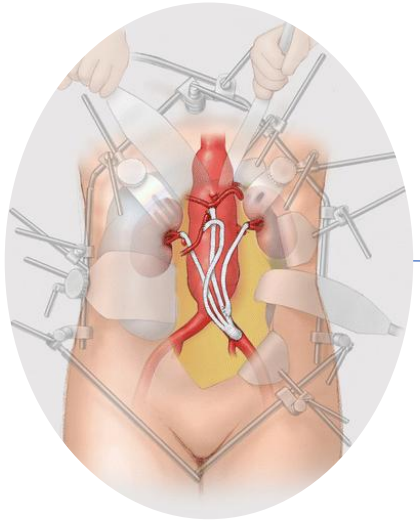
This convergence reshapes how we define roles, tools, and responsibilities.

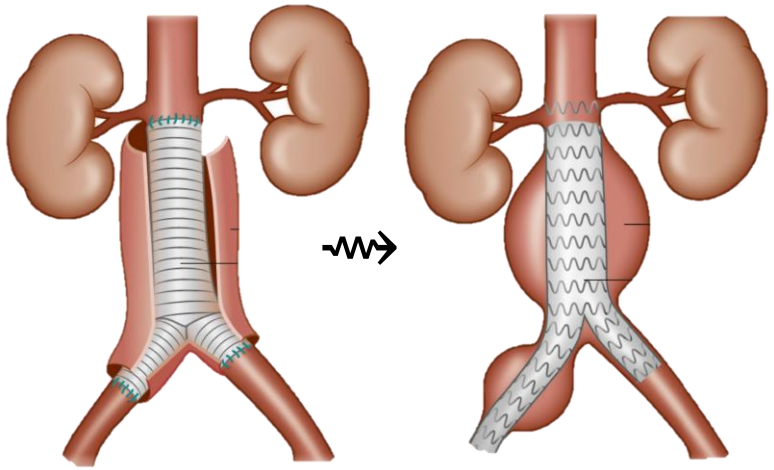
Open ⇝ Video-assisted (laparosocopic)



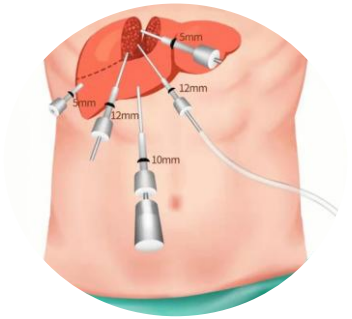
Dallemagne B. WebSurg, 2020

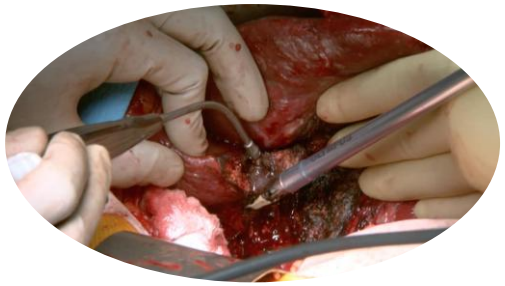
Open ⇝ Endovascular

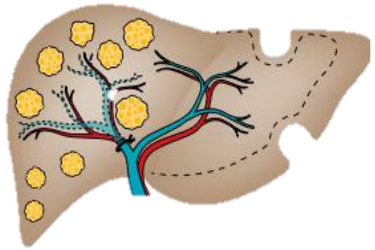




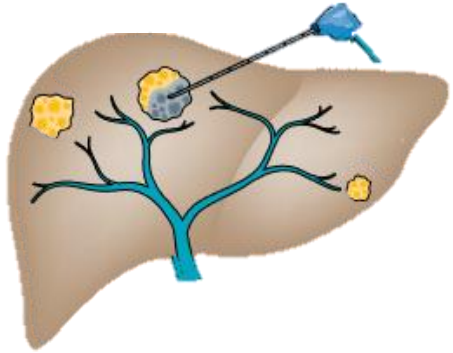
Liver Resection ⇝ Tumor Ablation

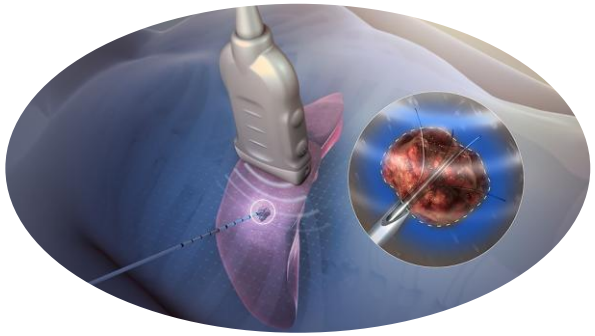






⇝





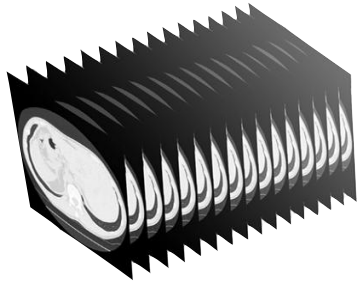
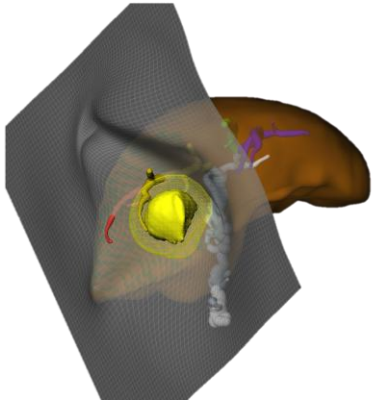
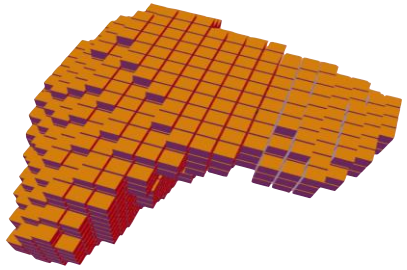
modified from - Petrowsky, H. *et al. Nat Rev Gastroenterol Hepatol*, 2020

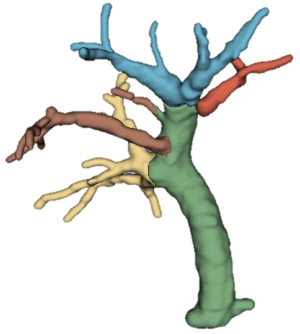
Medical Imaging Innovation: Paradigm Shifts

Domain	Old Paradigm	New Paradigm	Catalyst	Clinical Outcome
Liver Surgery	Open Hepatectomy	Laparoscopic/Robotic Hepatectomy	Minimally invasive tools, robotics	↓ Morbidity, ↓ stay, faster recovery
	Resection with visual guidance only	Image-guided (US), parenchyma-sparing surgery	Intraop ultrasound, ICG, AI	↑ R0 rate, preserved function
Pancreatic Surgery	Pancreatectomy	Laparoscopic/Robotic Pancreatectomy	Robotic dexterity, structured learning pathways	Comparable outcomes, fewer wound issues, ↓ Bleeding, ↓ recovery time
	Open necrosectomy for pancreatitis	Endoscopic necrosectomy	Minimally invasive drainage + debridement	↓ Sepsis, fewer ICU days, faster resolution
Digestive Surgery	Open cholecystectomy	Laparoscopic cholecystectomy	Early laparoscopy innovators	Became standard of care (shorter stay, less pain)
	Open fundoplication	Transoral Incisionless Fundoplication (TIF)	GERD-focused endoscopic platforms	Incisionless outpatient anti-reflux option
	Resection for all early GI tumors	Endoscopic Submucosal Dissection (ESD) / Mucosal Resection (EMR)	High-definition endoscopy, specialized tools	Curative without surgery in early-stage cancer
	Surgery with abdominal access for obesity	Endoscopic Sleeve Gastroplasty (ESG)	Endoluminal suturing tech, obesity therapy demand	Outpatient, no incisions, promising short-term weight loss
Vascular Surgery	Open AAA repair via laparotomy	Endovascular Aneurysm Repair (EVAR)	Stent grafts, fluoroscopic guidance	↓ Perioperative mortality, ↓ ICU use
	Open femoropopliteal bypass	Percutaneous angioplasty with drug-eluting technologies	Drug-eluting balloons, image guidance	Less invasive, faster ambulation
	Endarterectomy for carotid stenosis	Carotid artery stenting	Neuroprotection systems, better stent design	Less invasive, same-day discharge potential

MINIMALLY INVASIVE THERAPY

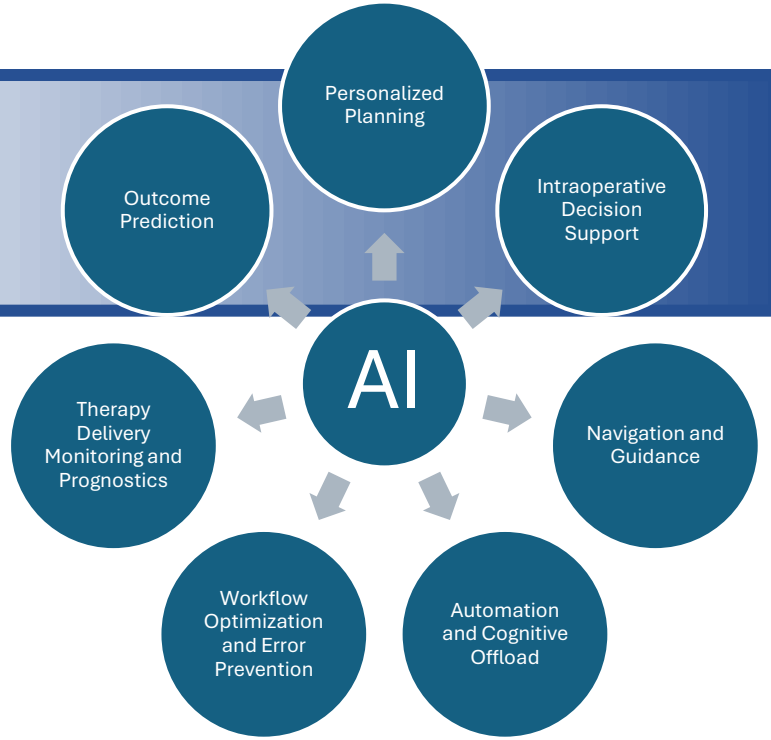
- **Evolution:** Shift from invasive to minimally invasive methods
- **Impact:** Reduced trauma, quicker recovery
- **Role of Imaging:** Reshaping procedural approaches
- **Paradigm Shifting**



BENEFITS

BENEFITS OF AI



Short-Term

- Precision
- Safety
- Efficiency
- Personalization
- Accessibility

Long-Term

- Digital Twins
- Augmented Reality (AR)
- Autonomous robotics
- Improved training

[LIVE]
10:16:49

AI-Assisted Laparoscopic Cholecystectomy

Project co-funded by ANR, IHU Strasbourg, Univ. Strasbourg, Région Grand-Est

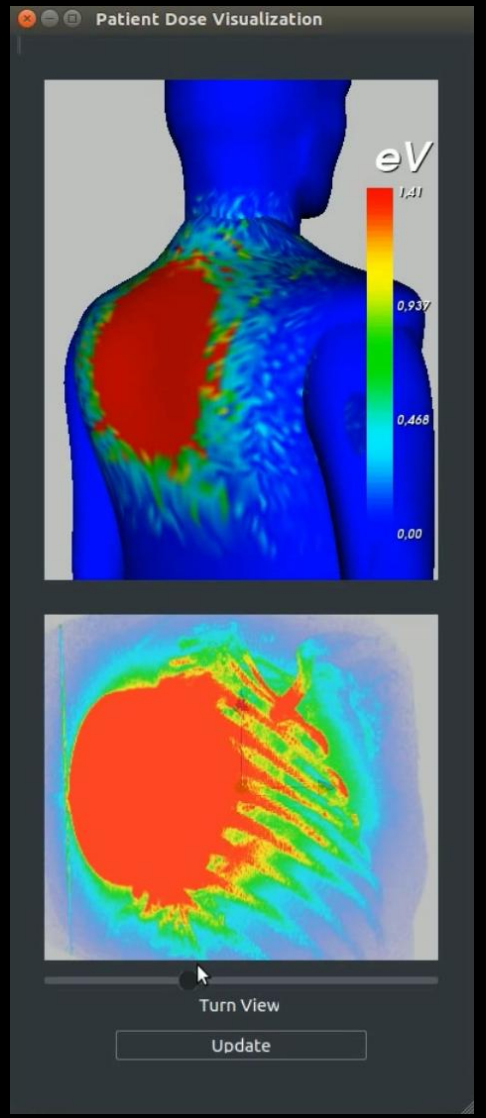
Mascagni et al.

X-ray Safety Monitoring

3D Propagation:

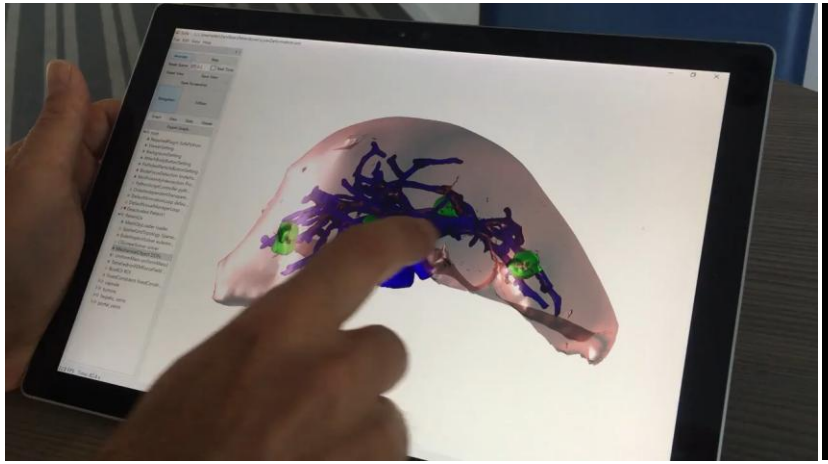
Body Parts:

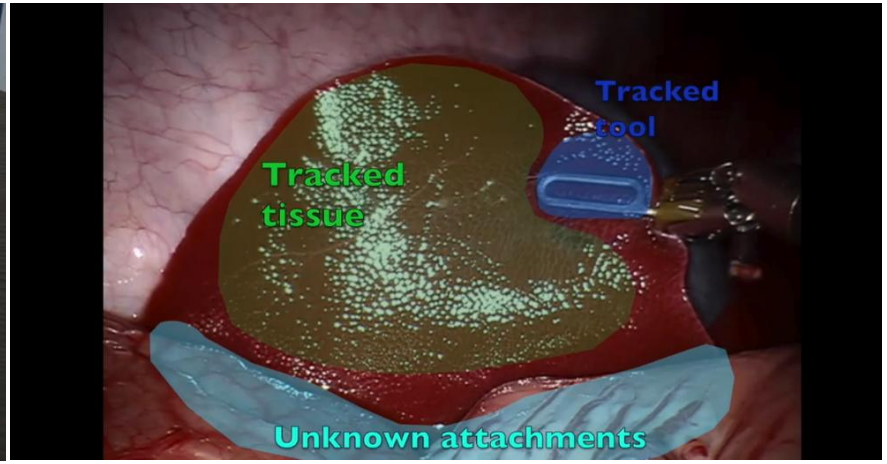
Patient:

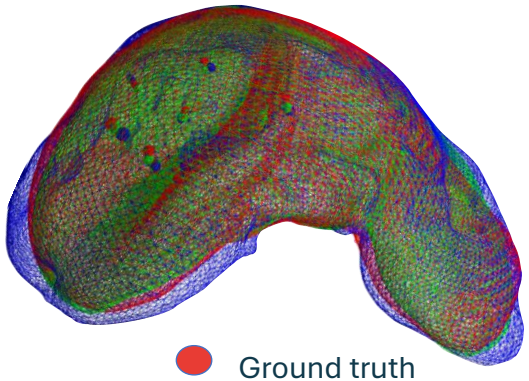


Project co-funded by ANR, IHU, Labex CAMI

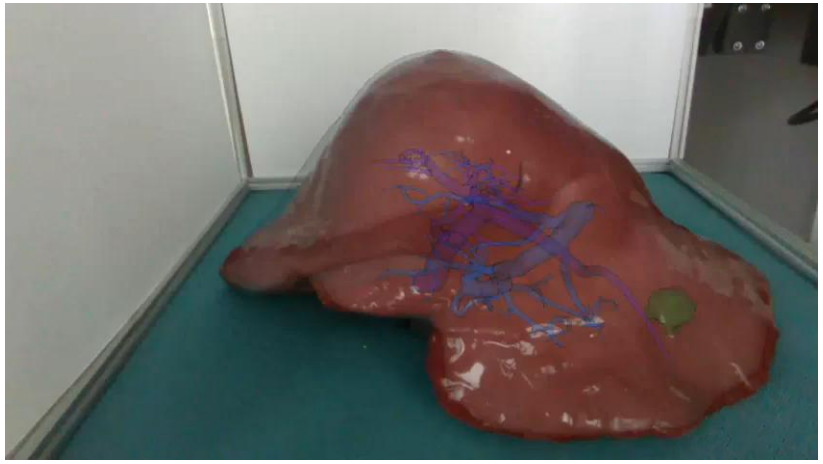
Loy Rodas et al.

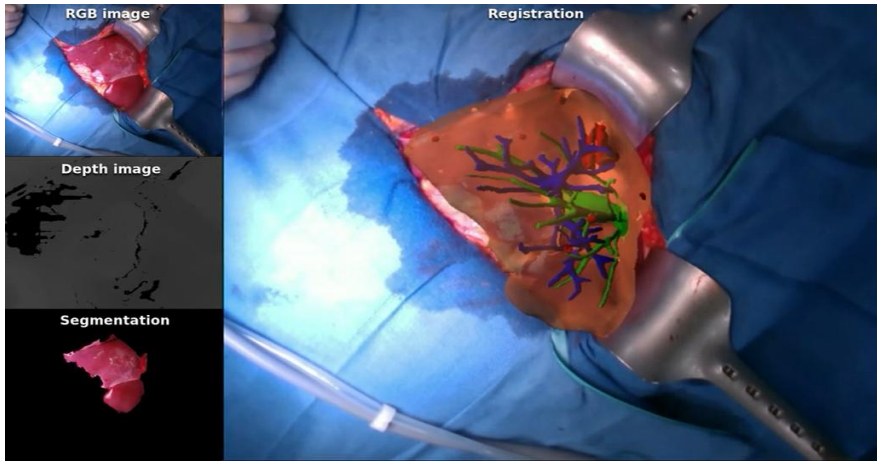


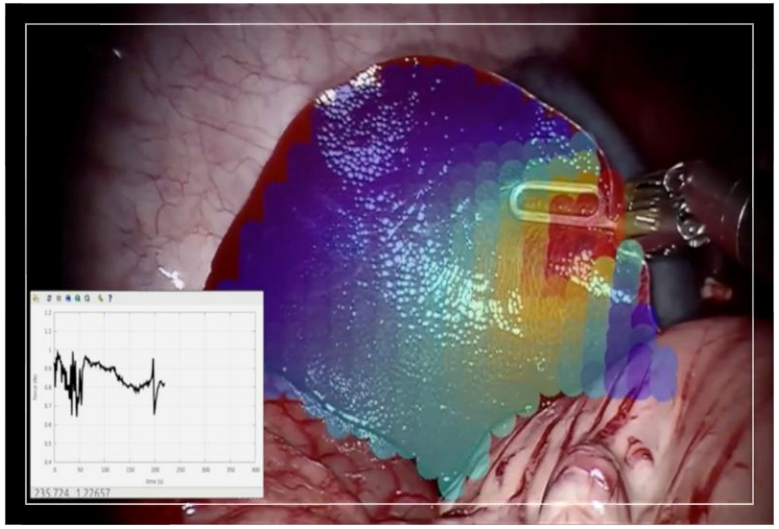


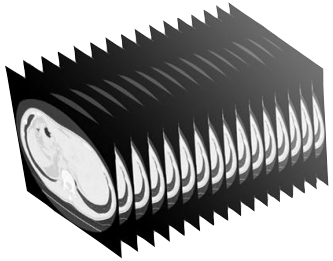


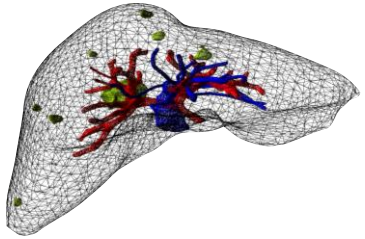
Ground truth
U-mesh prediction
FEM model

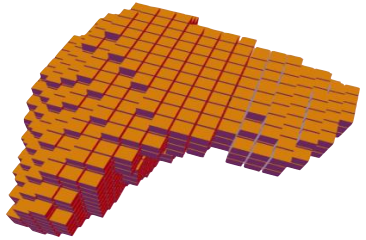


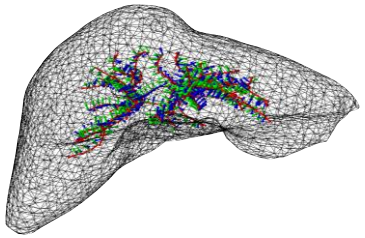


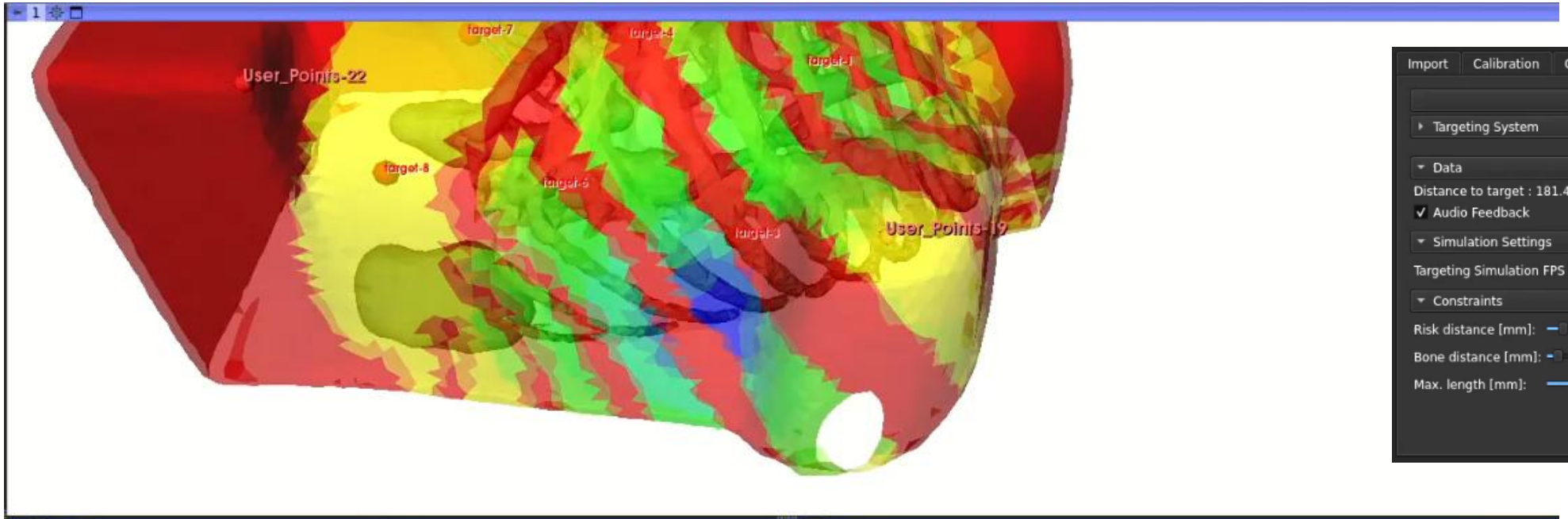








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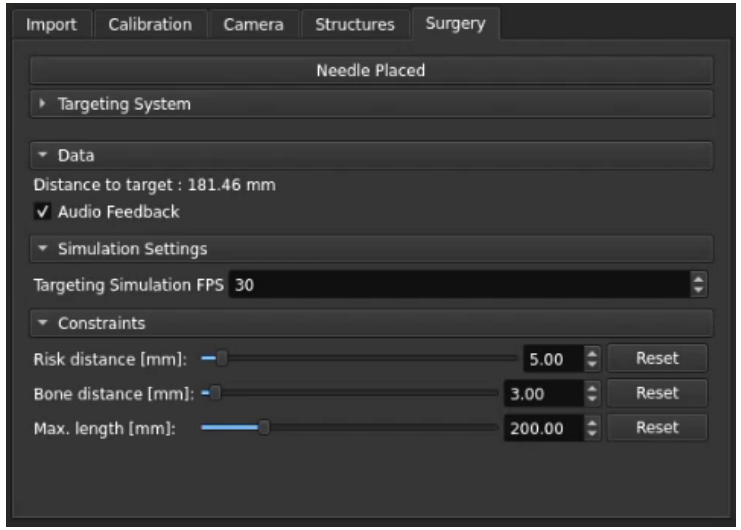
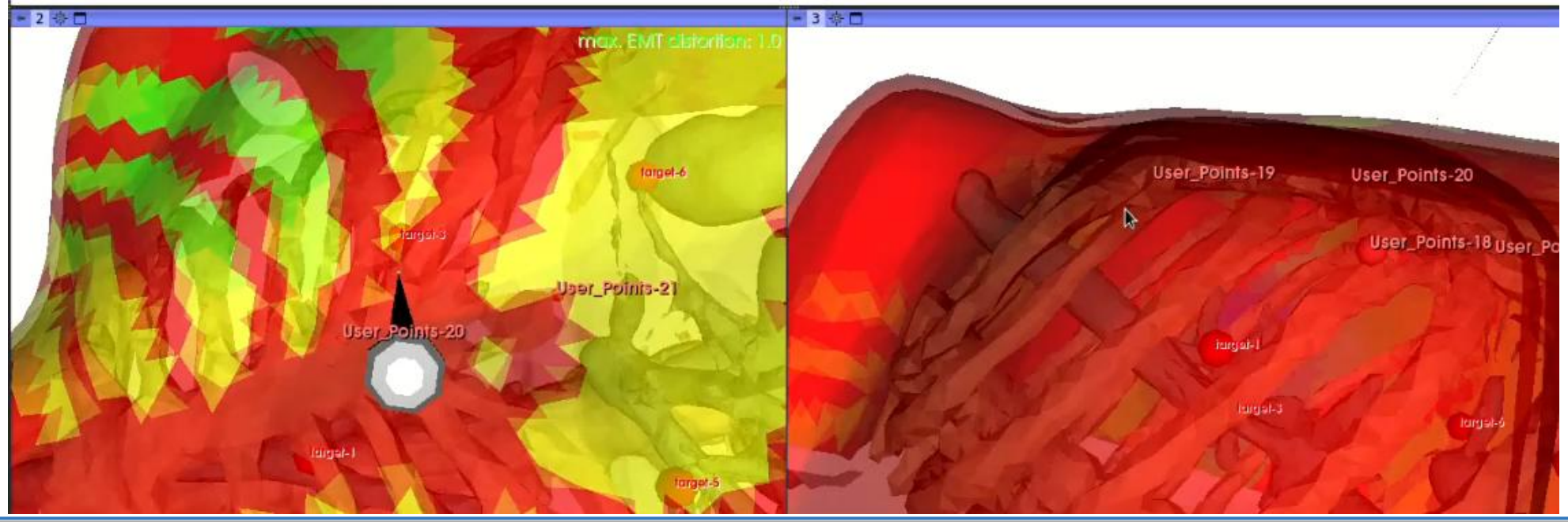
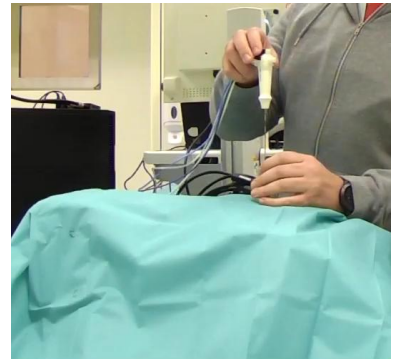
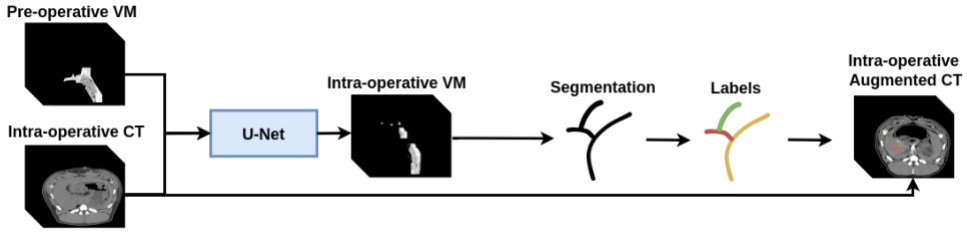
target-7
target-4
target-1
User_Points-22
target-8
target-6
target-5
User_Points-19

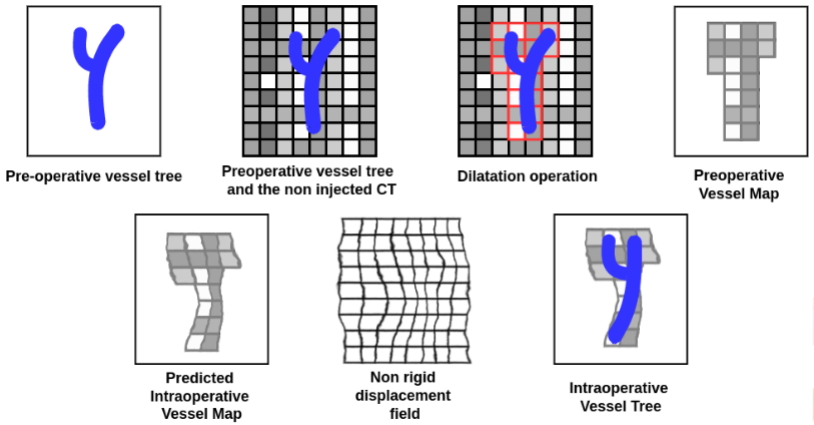

Import
Calibration
Camera
Structures
Surgery
Needle Placed
Targeting System
Data
Distance to target : 181.46 mm
Audio Feedback
Simulation Settings
Targeting Simulation FPS 30
Constraints
Risk distance [mm]: 5.00 Reset
Bone distance [mm]: 3.00 Reset
Max. length [mm]: 200.00 Reset

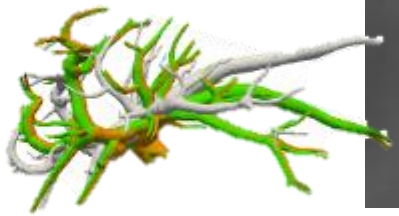

2
max. EMT distortion: 1.0
target-6
target-3
User_Points-21
User_Points-20
target-1
target-5

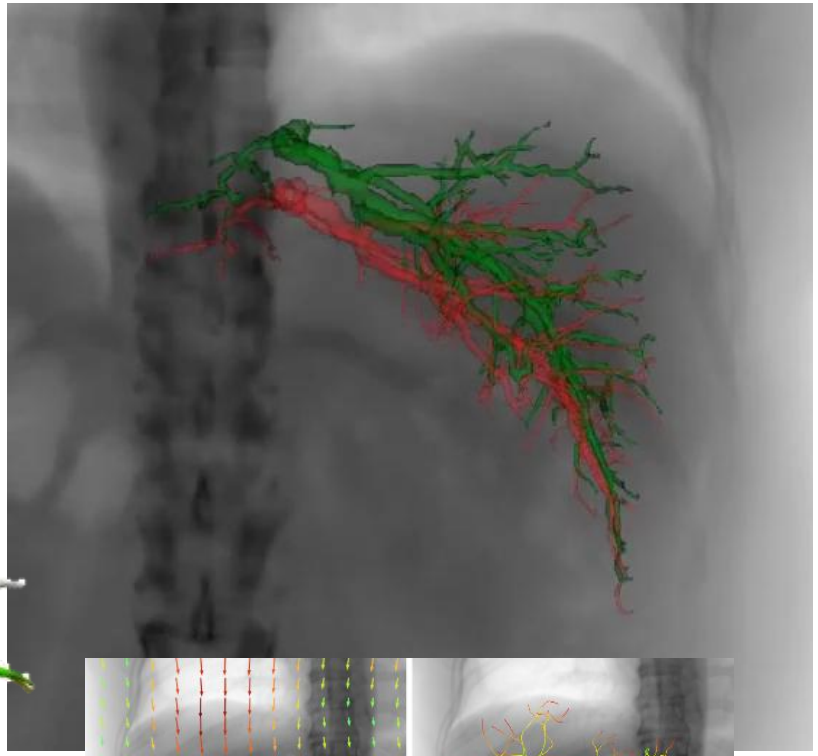
3
User_Points-19
User_Points-20
User_Points-18
target-1
target-3
target-6

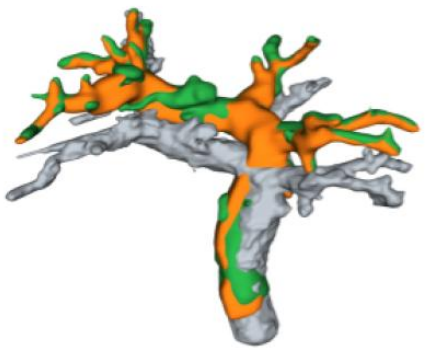


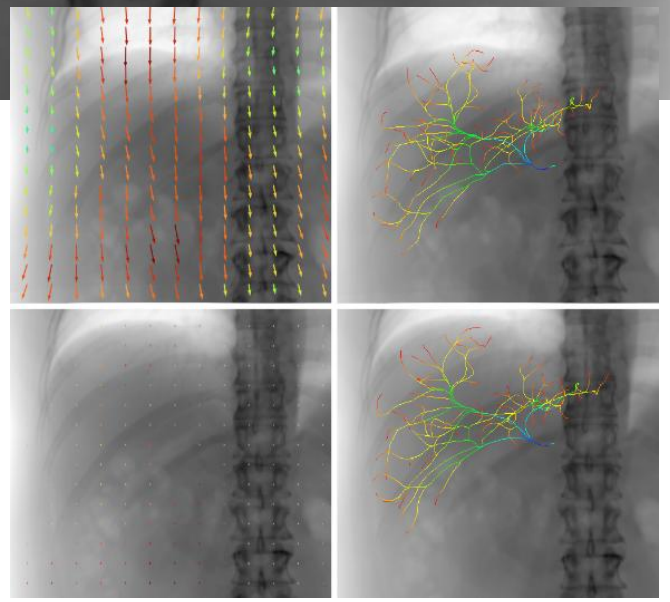

Pre-operative VM
Intra-operative CT
U-Net
Intra-operative VM
Segmentation
Labels
Intra-operative Augmented CT

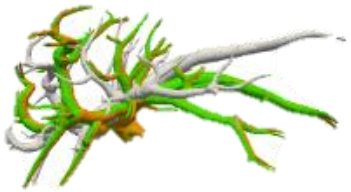

Pre-operative vessel tree
Preoperative vessel tree and the non injected CT
Dilatation operation
Preoperative Vessel Map
Predicted Intraoperative Vessel Map
Non rigid displacement field
Intraoperative Vessel Tree

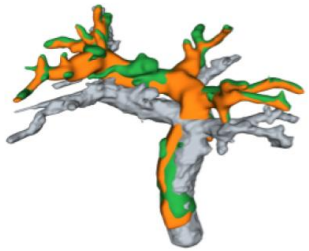


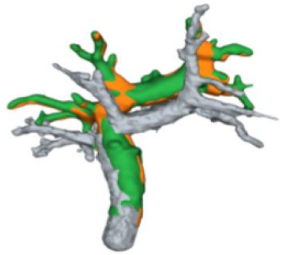


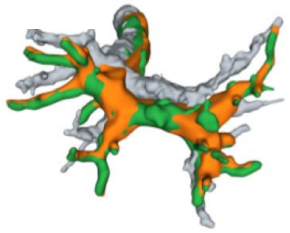


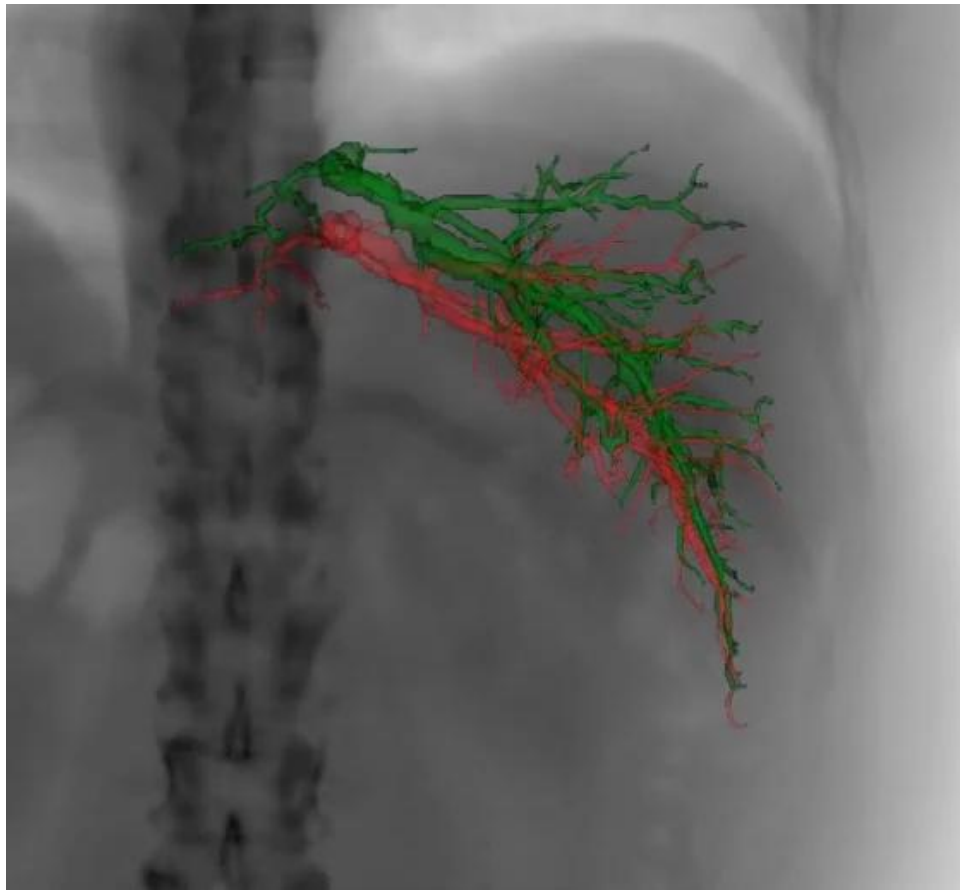


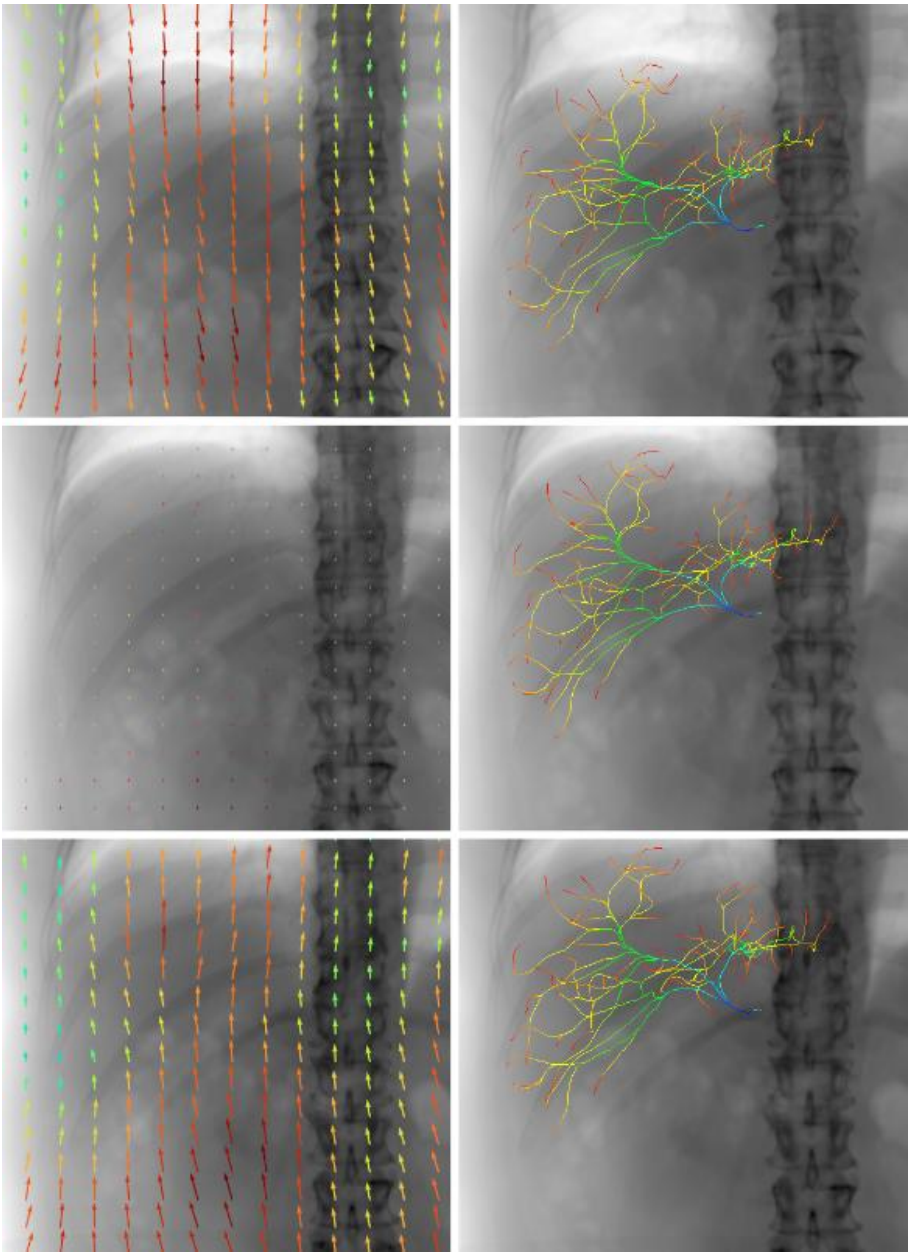


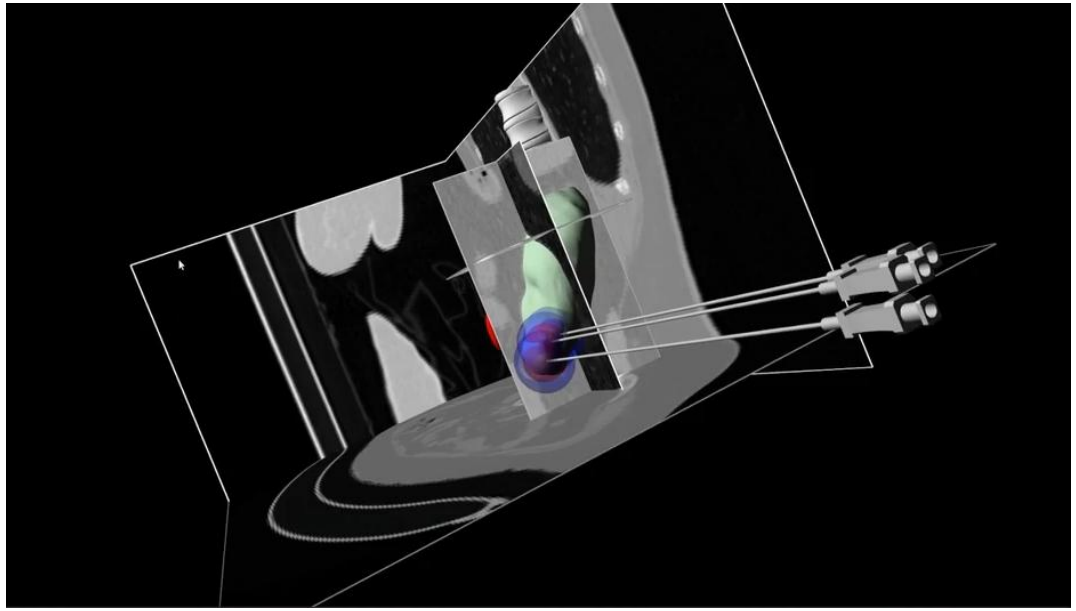


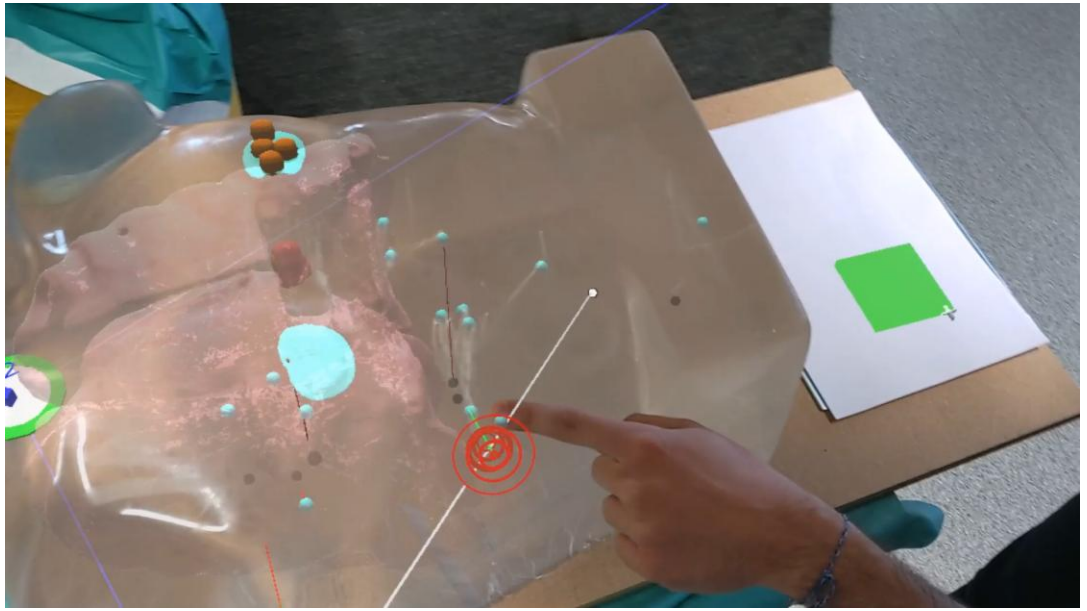




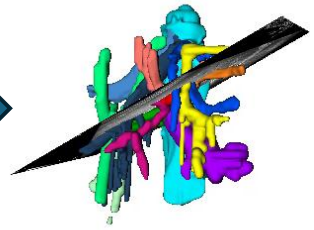


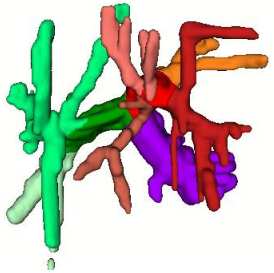


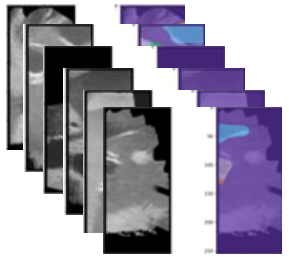


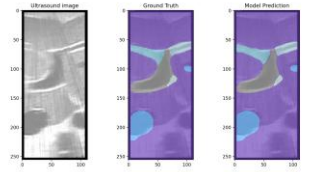


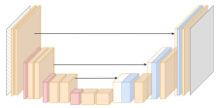
TECHNOLOGY / SOLUTION

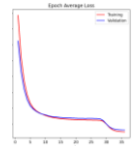


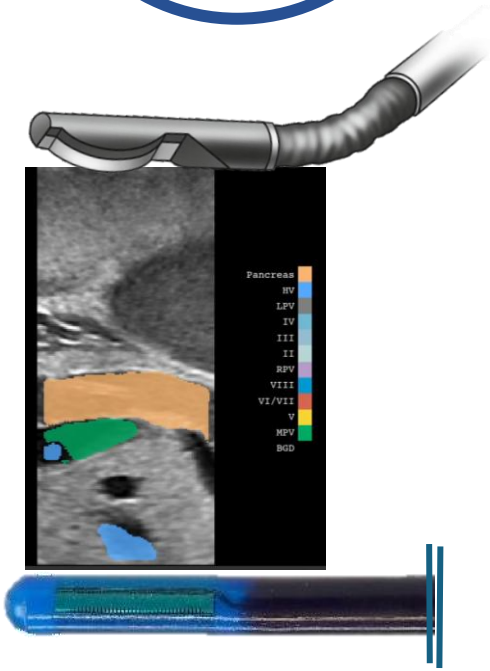




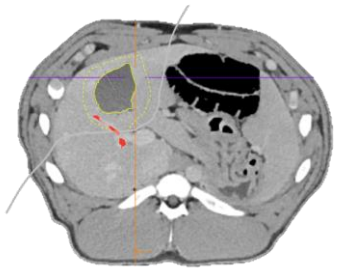


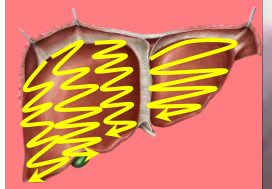


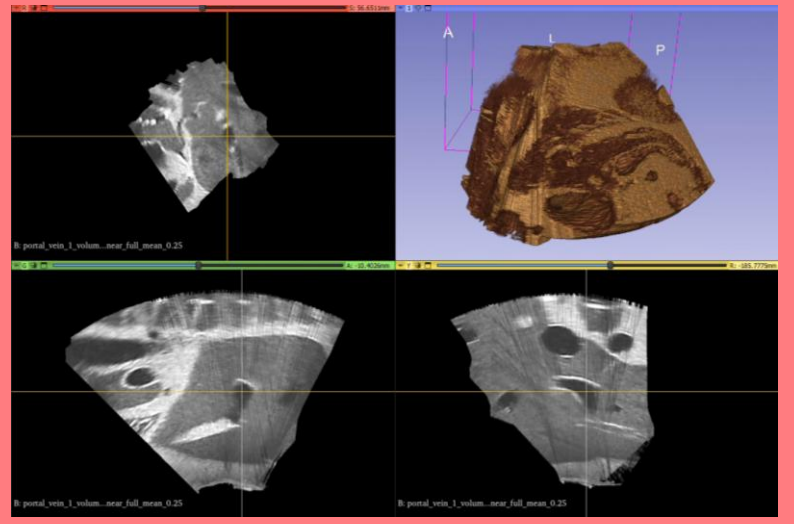


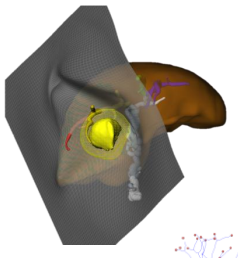


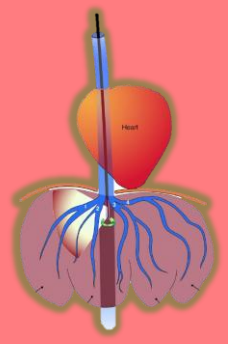
PREOPERATIVE

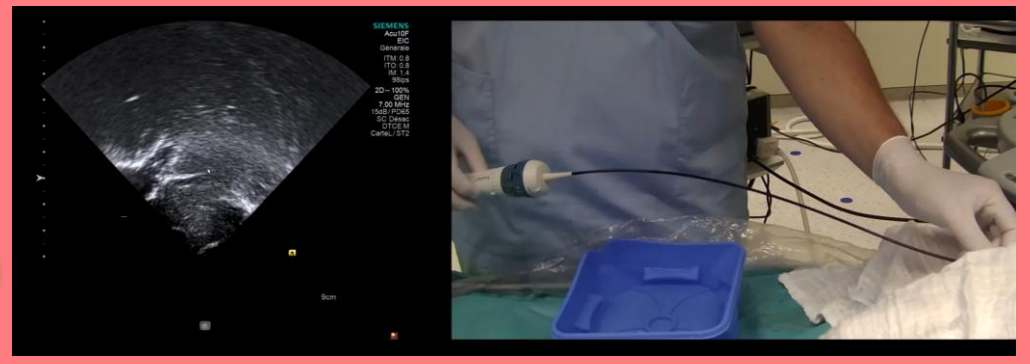


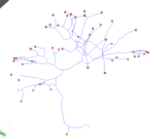


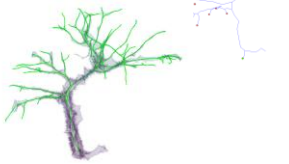


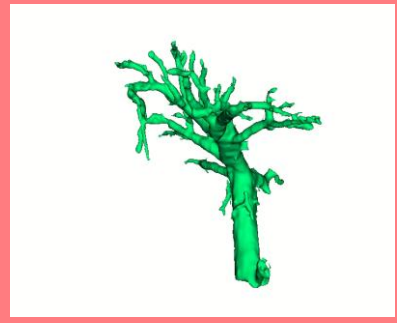


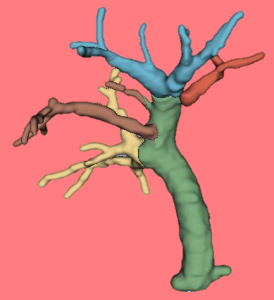


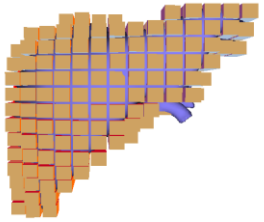


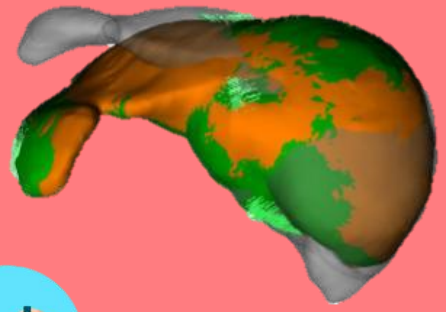


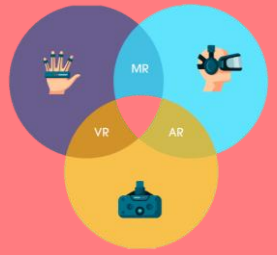


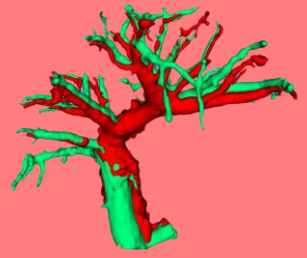


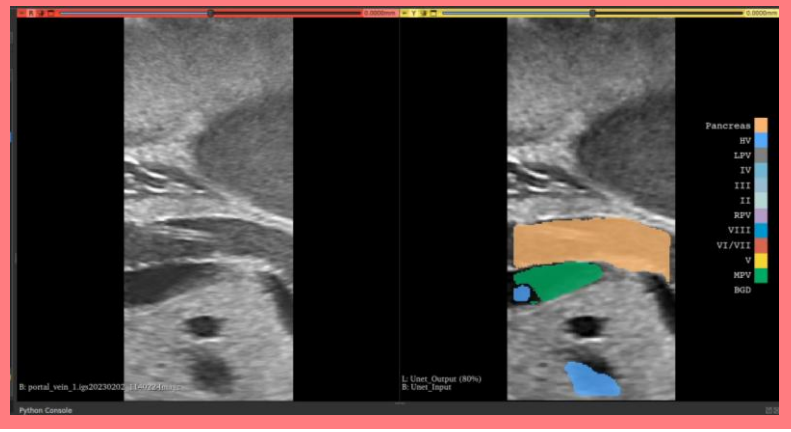


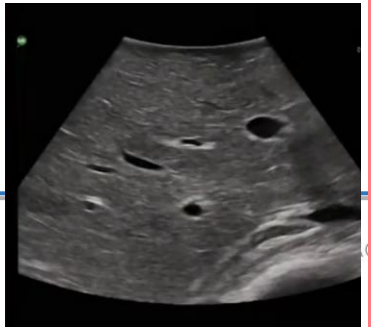




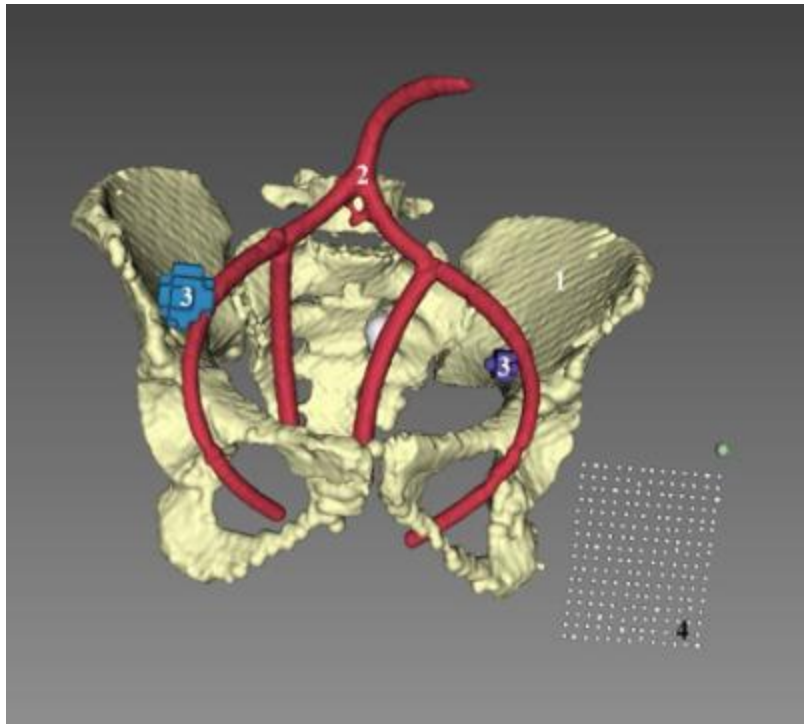








INTRAOPERATIVE



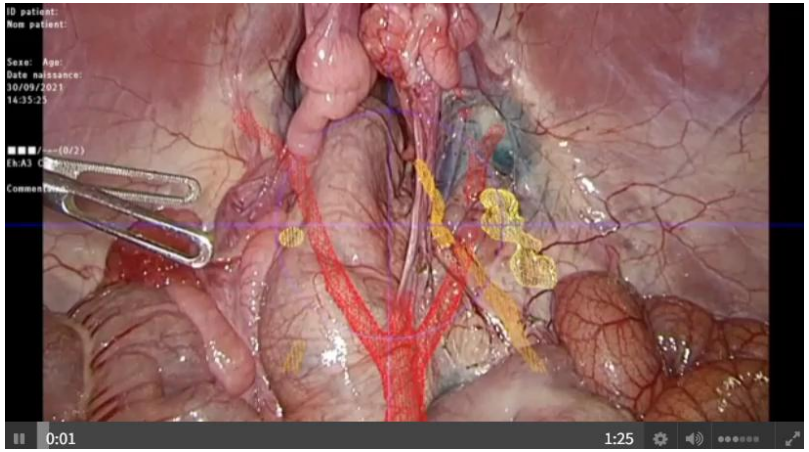
Original Article | Published: 13 July 2022

Robotically assisted augmented reality system for identification of targeted lymph nodes in laparoscopic gynecological surgery: a first step toward the identification of sentinel node

Augmented reality in gynecological surgery

Lise Lecointre, Juan Verde, Laurent Goffin, Aïna Venkatasamy, Barbara Seeliger, Massimo Lodi, Lee L. Swanström, Chérif Akladios & Benoît Gallix

Surgical Endoscopy **36**, 9224–9233 (2022) | Cite this article

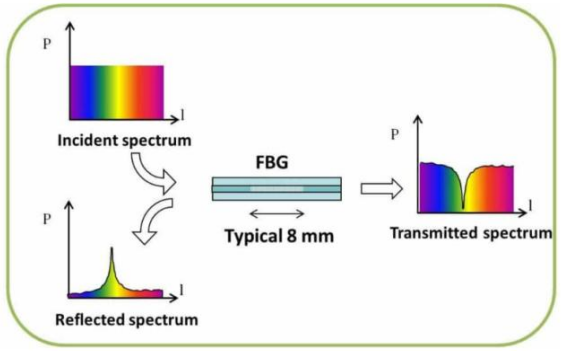


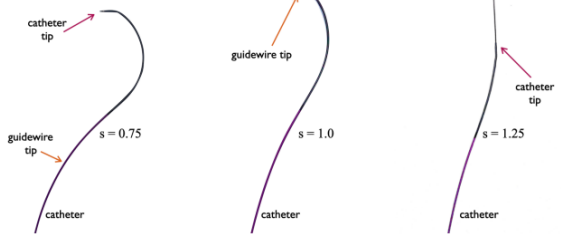
Preoperative SPECT/CT + intraoperative CT fusion enabling surgical augmented reality to target sentinel lymph node in endometrial cancer

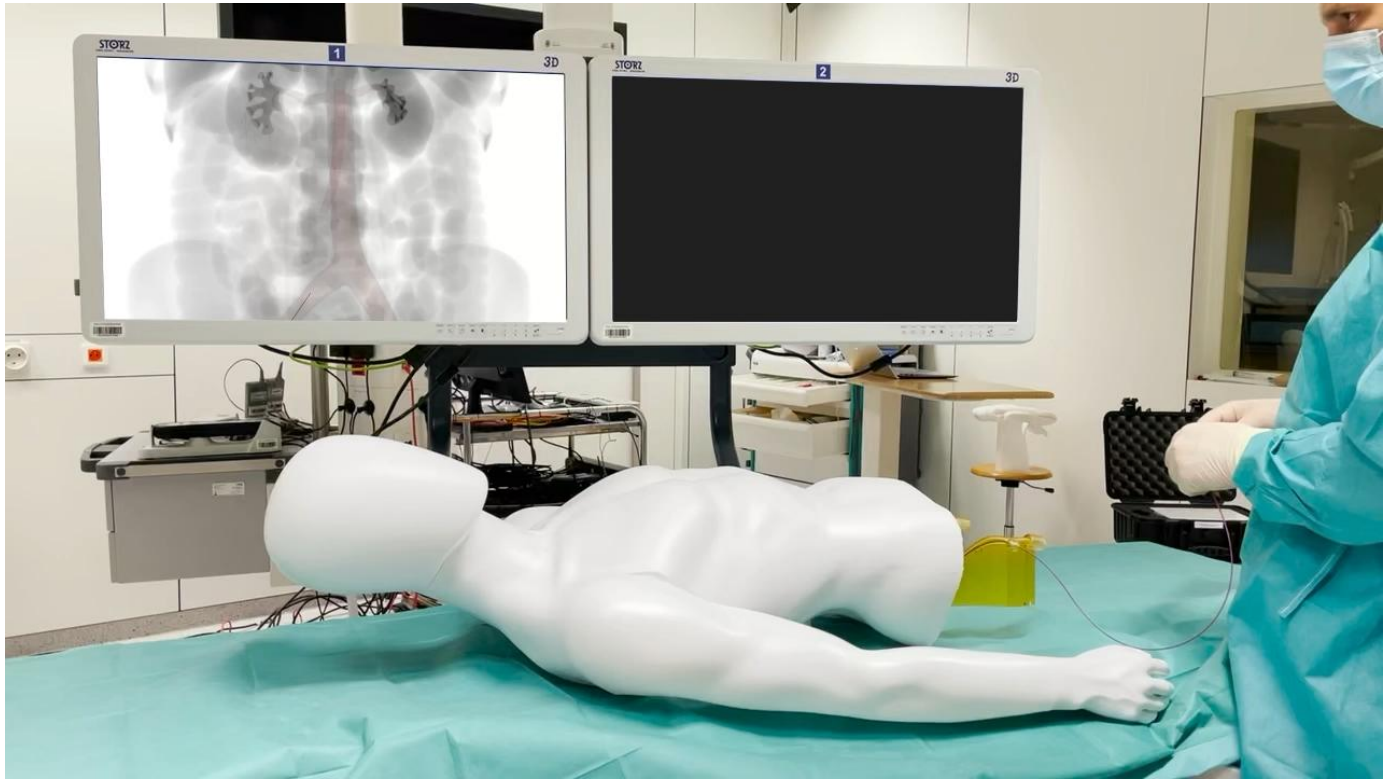
Lise Lecointre[1,2,3*], Juan Verde[2], Fabrice Hubele[4], Julien Salvadori[4], Laurent Goffin[2,3], Chérif Akladios[1] and Benoît Gallix[2,3,5]

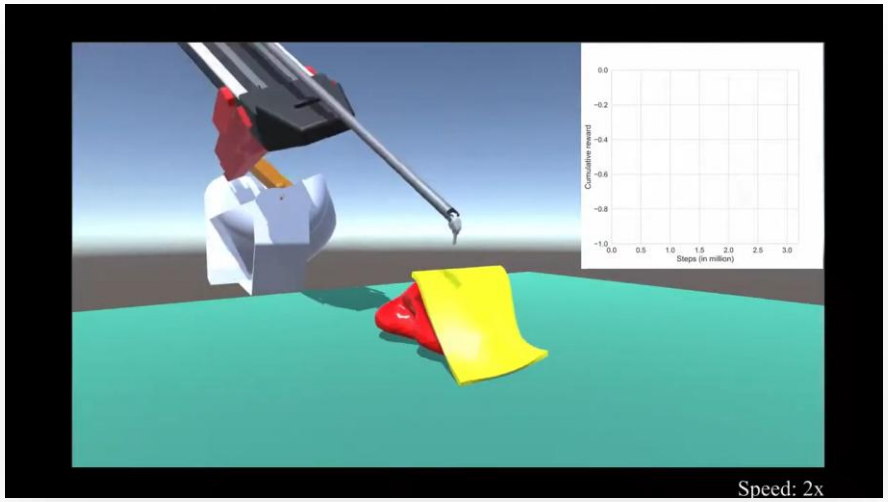
Robotically assisted AR

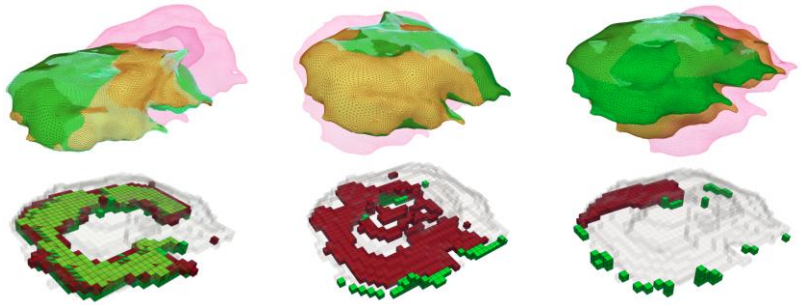
Predicted Mixed Reality: Towards Safer and Efficient Endovascular Interventions

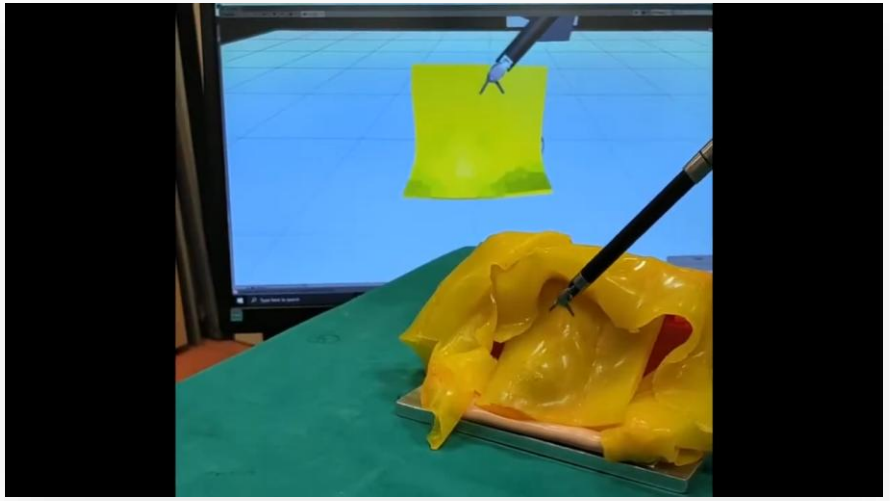


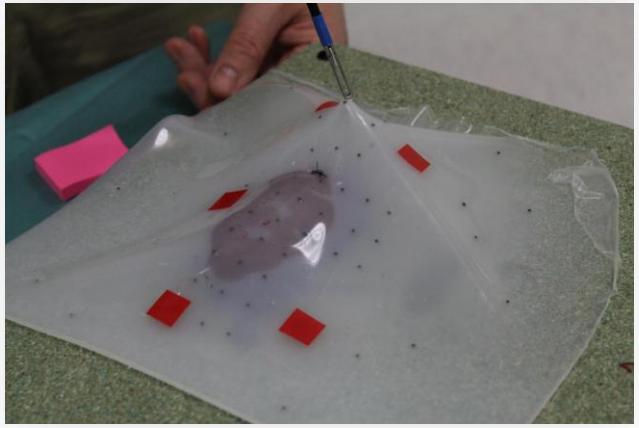










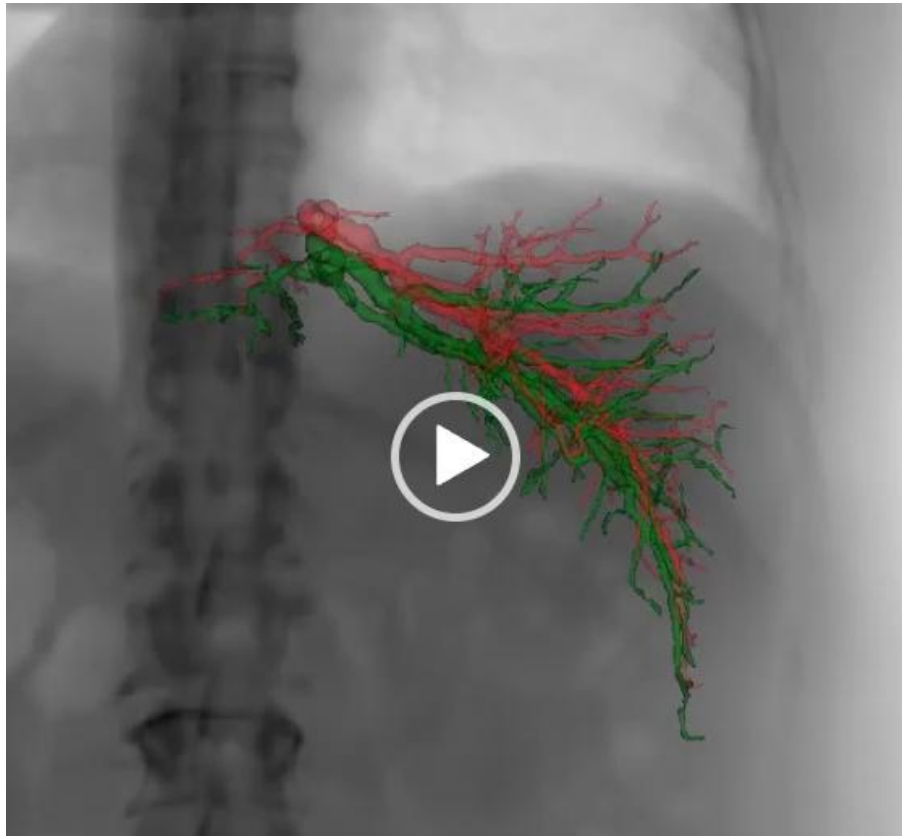


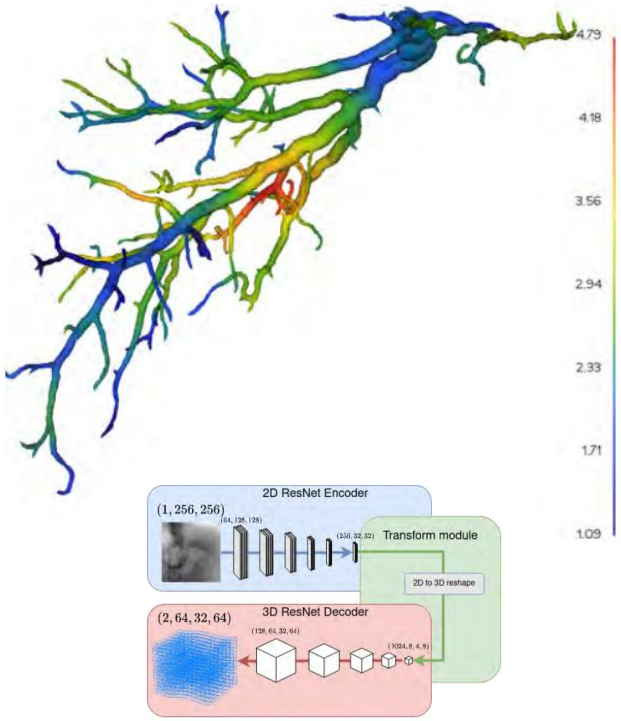
Intra-operative Update of Boundary Conditions for Patient-specific Surgical Simulation

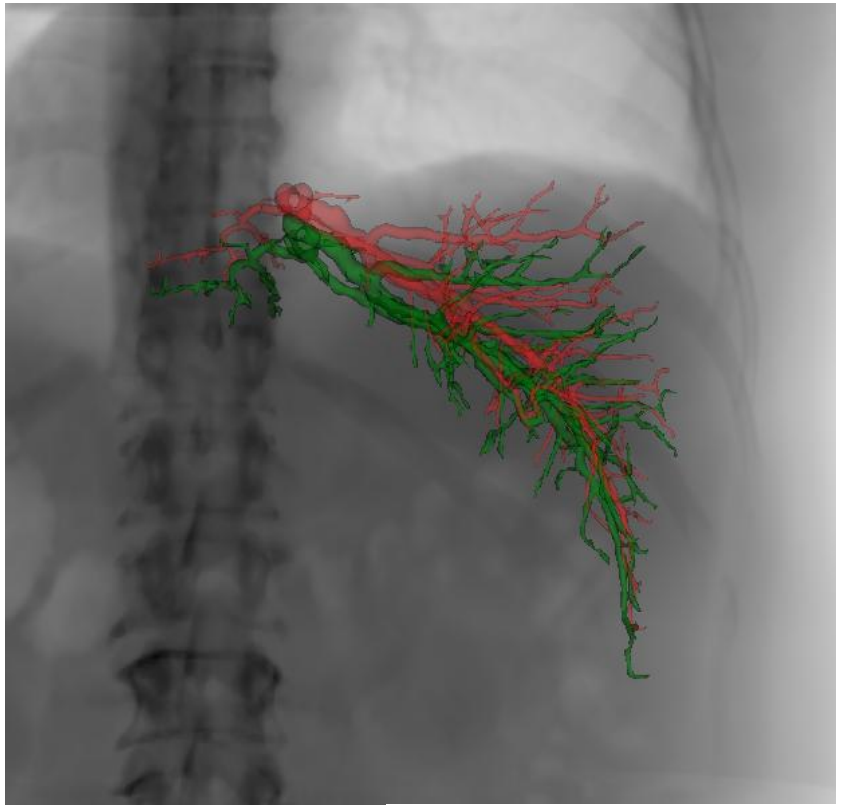
Eleonora Tagliabue[1], Marco Piccinelli[1], Diego Dall'Alba[1], Juan Verde[2], Micha Pfeiffer[3], Riccardo Marin[4], Stefanie Speidel[3], Paolo Fiorini[1], and Stéphane Cotin[5]

[1] University of Verona, Verona, Italy (eleonora.tagliabue@univr.it)
[2] Institut de Chirurgie Guide par l'Image, Strasbourg, France
[3] National Center for Tumor Diseases, Dresden, Germany
[4] Sapienza University of Rome, Rome, Italy
[5] INRIA, Strasbourg, France

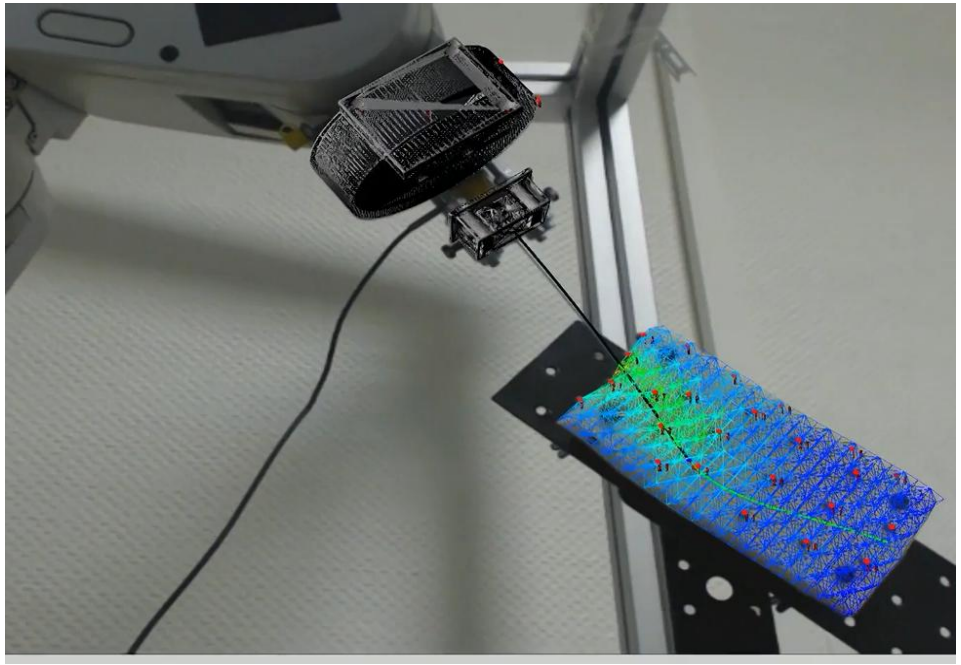
Enhancing Fluoroscopy-Guided Interventions: a Neural Network to Predict Vessel Deformation without Contrast Agents

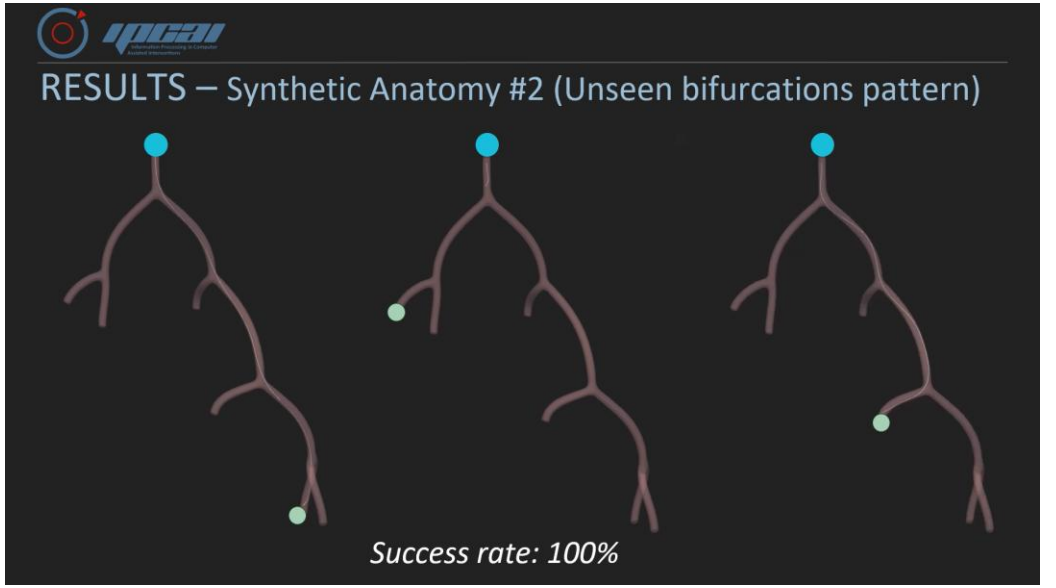


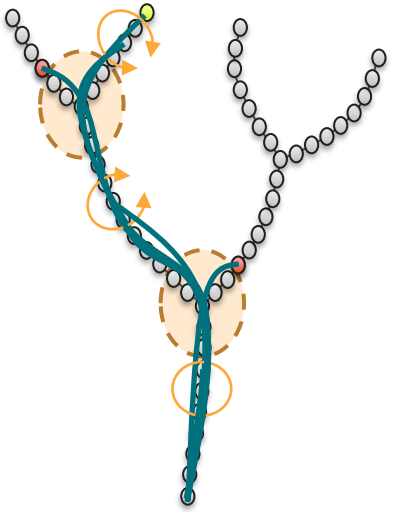




HSMR2023: THE 15TH HAMLYN SYMPOSIUM ON MEDICAL ROBOTICS
10.31256/HSMR2023.38




RESULTS – Synthetic Anatomy #2 (Unseen bifurcations pattern)
Success rate: 100%



CHALLENGES

AI INTEGRATION CHALLENGES

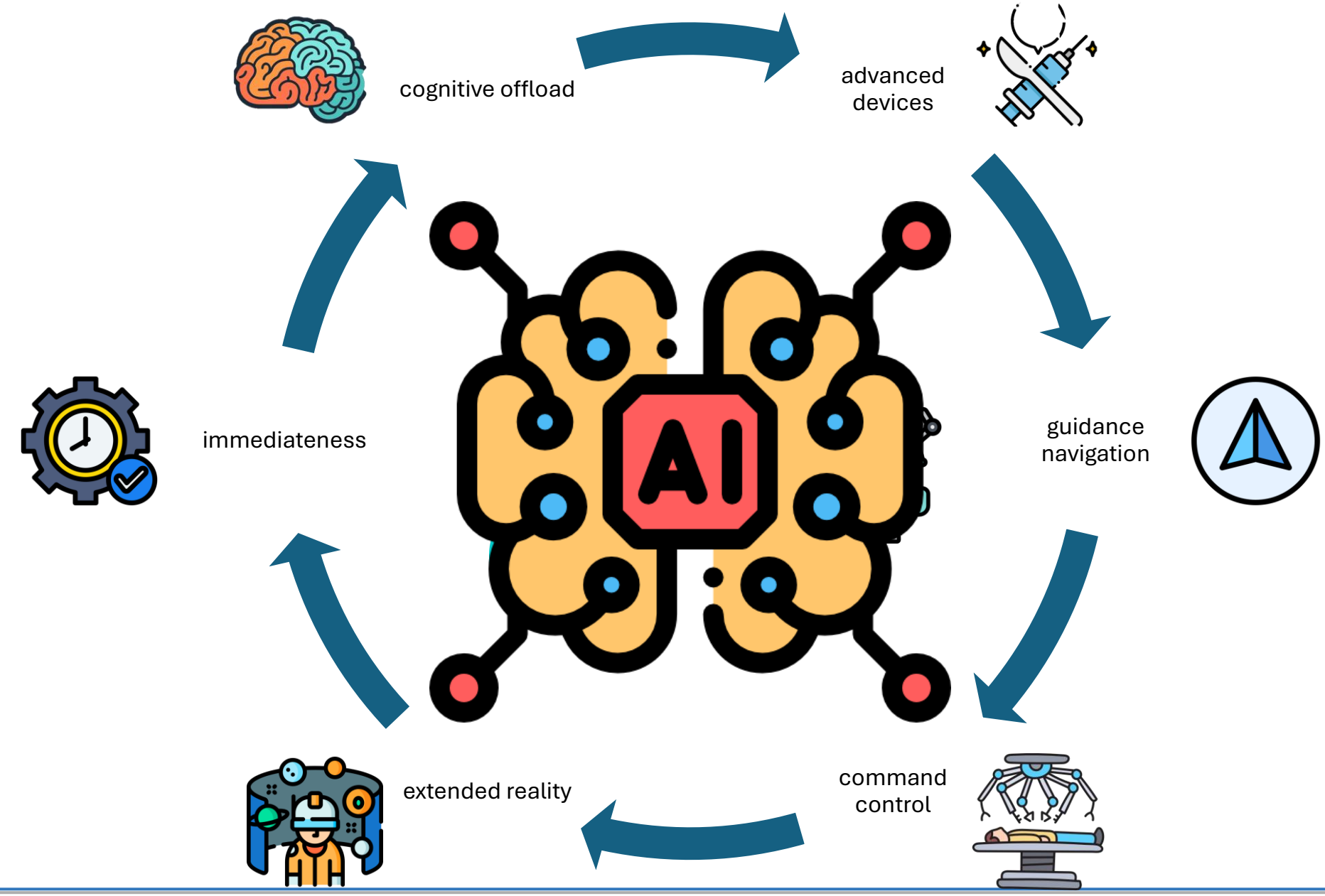
- **Workflow**: Real-time seamless integration, intuitive interfaces
- **Training**: Interdisciplinary staff training
- **Interoperability**: Standardized data compatibility

REGULATORY AND QUALITY ASSURANCE

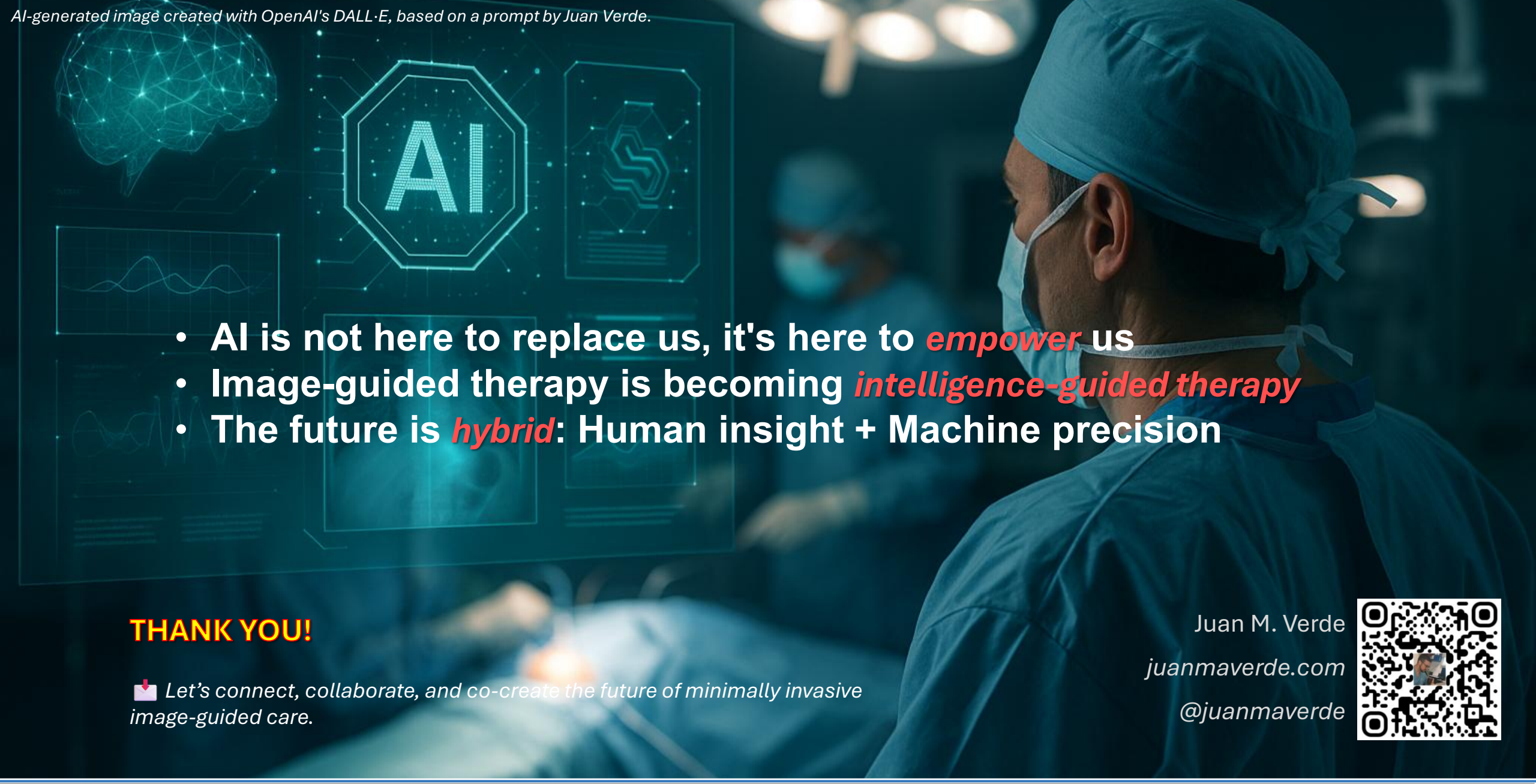
- **AI as Devices:** Regulatory approvals and standards
- **Standards Compliance:** ISO 42001:2023, EU AI Act
- **Validation:** Prospective trials, continuous monitoring
- **Ethical Oversight:** Transparency, bias mitigation
- **Accountability:** Clearly defined responsibility

FUTURE VISION

- **Regulation Alignment:** Early proactive involvement
- **Patient-Specific AI:** Personalized pre-op to intra-op guidance
- **Democratization:** Supporting clinicians with AI
- **AI-CROs:** Dedicated validation organizations for AI testing and de-risking


cognitive offload
advanced devices
AI
guidance navigation
command control
extended reality
immediateness

AI-generated image created with OpenAI's DALL·E, based on a prompt by Juan Verde.



- AI is not here to replace us, it's here to *empower* us
- Image-guided therapy is becoming *intelligence-guided therapy*
- The future is *hybrid*: Human insight + Machine precision

THANK YOU!

📩 *Let's connect, collaborate, and co-create the future of minimally invasive image-guided care.*

Juan M. Verde

juanmaverde.com

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