VIRTUAL, AUGMENTED AND MIXED REALITY: THE NEW FRONTIER OF LEARNING

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Fondatore MISSTO *– Multidisciplinary Italian Study group for STOmas*

Membro Education Task Force EHS *– European Hernia Society*

Evolution of surgical training: From Apprenticeship to Digital Innovation

SURGICAL PRACTICE THROUGH TIME

Apprenticeship System

Young surgeons learned by observing and assisting master surgeons. This hands-on approach was vital in an era lacking formal medical education.

Barber-Surgeons

Multi-skilled professionals who performed surgeries, bloodlettings, and haircuts. Their dual roles often led to conflicts of interest.

Medieval Hospitals

Church-run institutions provided basic care. Surgical procedures were risky and often performed in unsanitary conditions.

19th Century Revolution

1

2

3

MEDICAL SCHOOLS

Introduction of formal curricula and standardized training for surgeons.

ANESTHESIA & ANTISEPSIS

Development of safer surgical environments.

FIRST RESIDENCIES

Structured education programs for surgical specialization.

20th Century Innovation

HALSTEDIAN MODEL

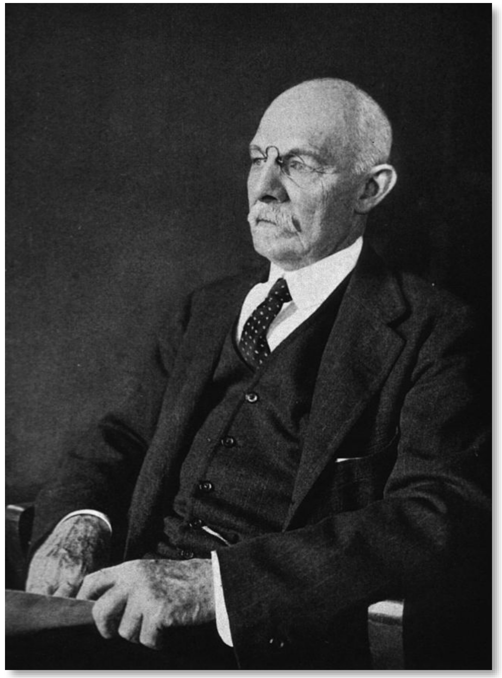
Hands-on training in residency programs revolutionized surgical education.

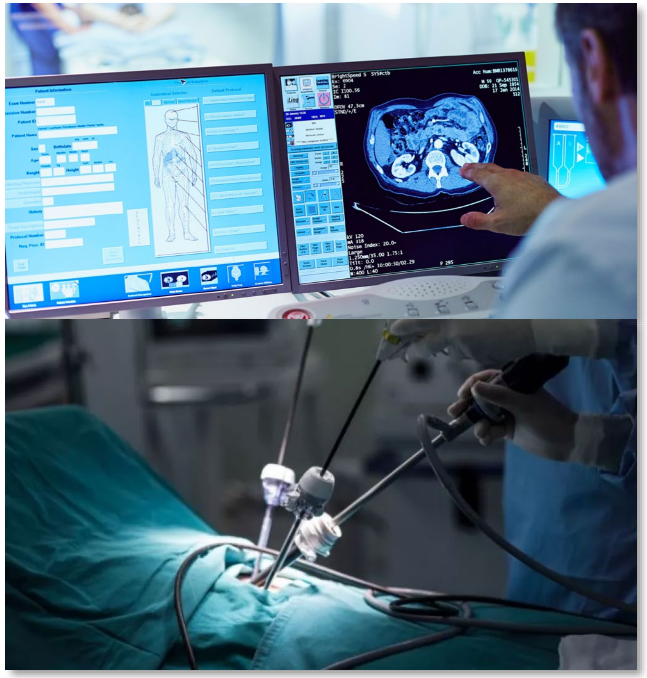
TECHNOLOGICAL ADVANCEMENTS

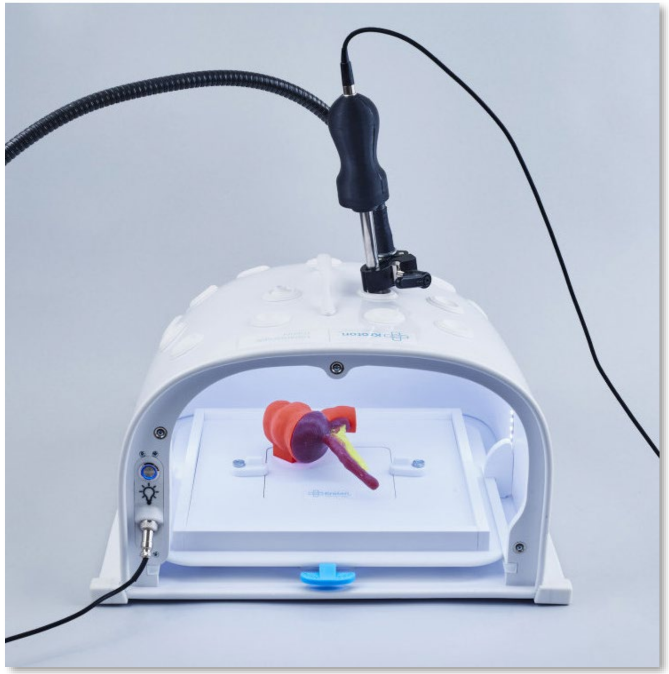
Early use of radiology and minimally invasive techniques transformed surgical practice.

SIMULATION MODELS

Introduction of synthetic materials for safe practice and skill development.







From industrial age to information technology age

IMPROVING THE QUALITY-REPRODUCIBILITY OF SURGERY

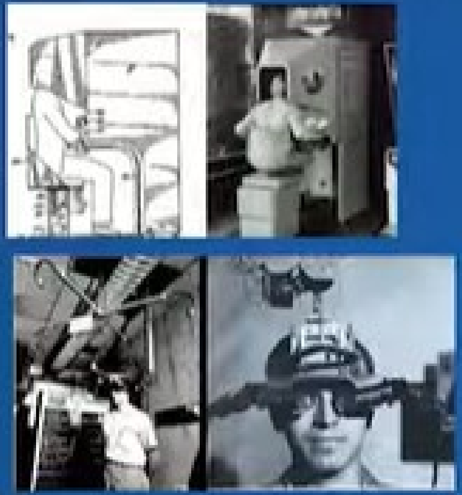
- Personalized surgery
- Intraoperative guidance
- Real time information
- Collaborative surgery
- Improved training

Digestive Health Institute Tampa

SAGES 2021

THE CONCEPT OF VIRTUAL AND AUGMENTED REALITY IS NOTHING NEW

1960's



1980's

1990's

2000's

2010 & Beyond

TAVAC Subcommittee

Helig, M.L. (1962). *U.S.Patent 3,050,870.* Washington, DC: U.S. Patent and Trademark Office

Sutherland, I. E. (1968). *A head-mounted three dimensional display.* Paper presented at the Proceedings of the December 9-11, 1968, fall joint computer conference, part I, San Francisco, California.

Fisher, S. S., McGreevy, M., Humphries, J., & Robinett, W. (1987). *Virtual environment display system.* Paper presented at the Proceedings of the 1986 workshop on Interactive 3D graphics, Chapel Hill, North Carolina.

Google GLASS
ENTERPRISE EDITION

2013

Review > JMIR Mhealth Uhealth. 2018 Mar 6;6(3):e54. doi: 10.2196/mhealth.9409.

Using Google Glass in Surgical Settings: Systematic Review

Nancy J Wei [1], Bryn Dougherty [1], Aundria Myers [1], Sherif M Badawy [2] [3] [4]

Affiliations + expand

PMID: 29510969 PMCID: PMC5861300 DOI: 10.2196/mhealth.9409

- June 2013: **Dr Rafael J. Grossmann**, the first surgeon to demonstrate the use of Google Glass during a live surgical procedure.
- August 2013, Google Glass was used at Wexner Medical Center at Ohio State University.
- Surgeon **Dr. Christopher Kaeding** used Google Glass to consult with a distant colleague in Columbus, Ohio.
- A group of students at The Ohio State University College of Medicine observed the operation on their laptop computers.
- Dr Pedro Guillen, chief of trauma service of Clínica CEMTRO of Madrid, also broadcast a surgery using Google Glass.
- July 2014: the startup company Surgery Academy, in Milan, launched a remote training platform for medical students. 19

- **Privacy concerns**
- **High price:** Google Glass was initially priced at $1,500
- **Limited functionality:** Google Glass was initially limited in terms of its functionality.
- **Poor design:** Google Glass was not well-designed for everyday use. It was bulky and uncomfortable to wear, and it was difficult to use the controls.

Glass Enterprise Edition Announcement FAQ

Last updated: March 15, 2023

As of March 15, 2023, we will no longer sell Glass Enterprise Edition. We will continue supporting Glass Enterprise Edition as described in the FAQs below until September 15, 2023.

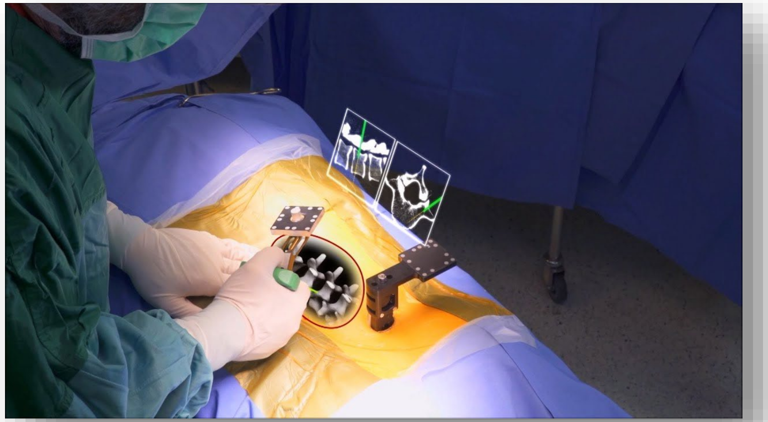
Extended Reality (XR) Technologies

VIRTUAL REALITY (VR)

VR immerses users in a fully digital environment. It is used for pre-operative planning and surgical simulation.

AUGMENTED REALITY (AR)

AR overlays digital information onto the real world. It can provide real-time guidance and anatomical insights during surgery.



MIXED REALITY (MR)

MR combines elements of VR and AR, allowing users to interact with both real and digital objects. It facilitates collaborative training and patient education.

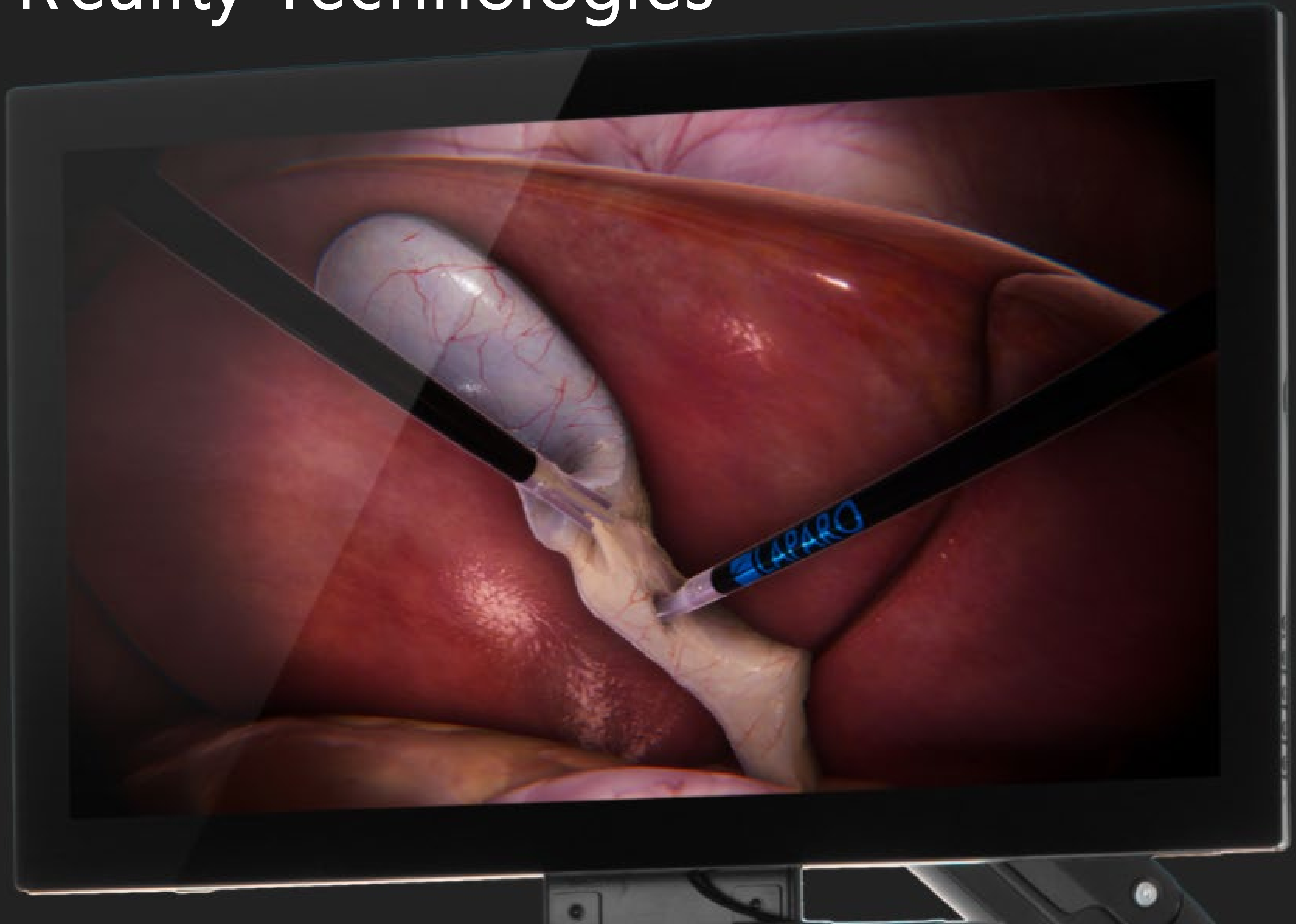
Virtual Reality (VR)

- Creates a completely digital environment where the user is fully immersed.
- Requires VR headsets (e.g., Oculus Quest, HTC Vive, etc.)
- Replaces the real world with a computer-generated one.
- Used in gaming, training (e.g., flight simulations), and desig

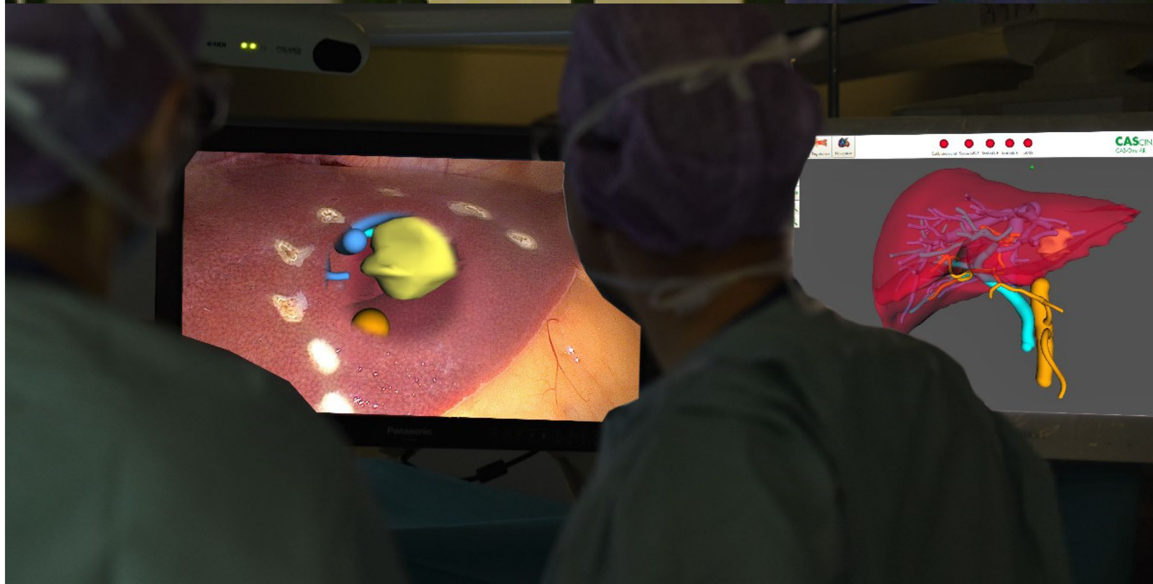
Fully virtual world


Full-HD
stereo-3D HMD
htc
The HMD uses an OLED panel for each eye.
It uses two lenses that allow for a wide field of view.

Virtual Reality Technologies



Virtual Reality (VR) in Surgical Training



✓ **Haptic Feedback & Realistic Simulation**

• Some VR systems integrate **haptic gloves and controllers** to simulate the feeling of tissues and surgical tools.

• Enhances **hand-eye coordination and motor skills**.

✓ **Remote & Collaborative Training**

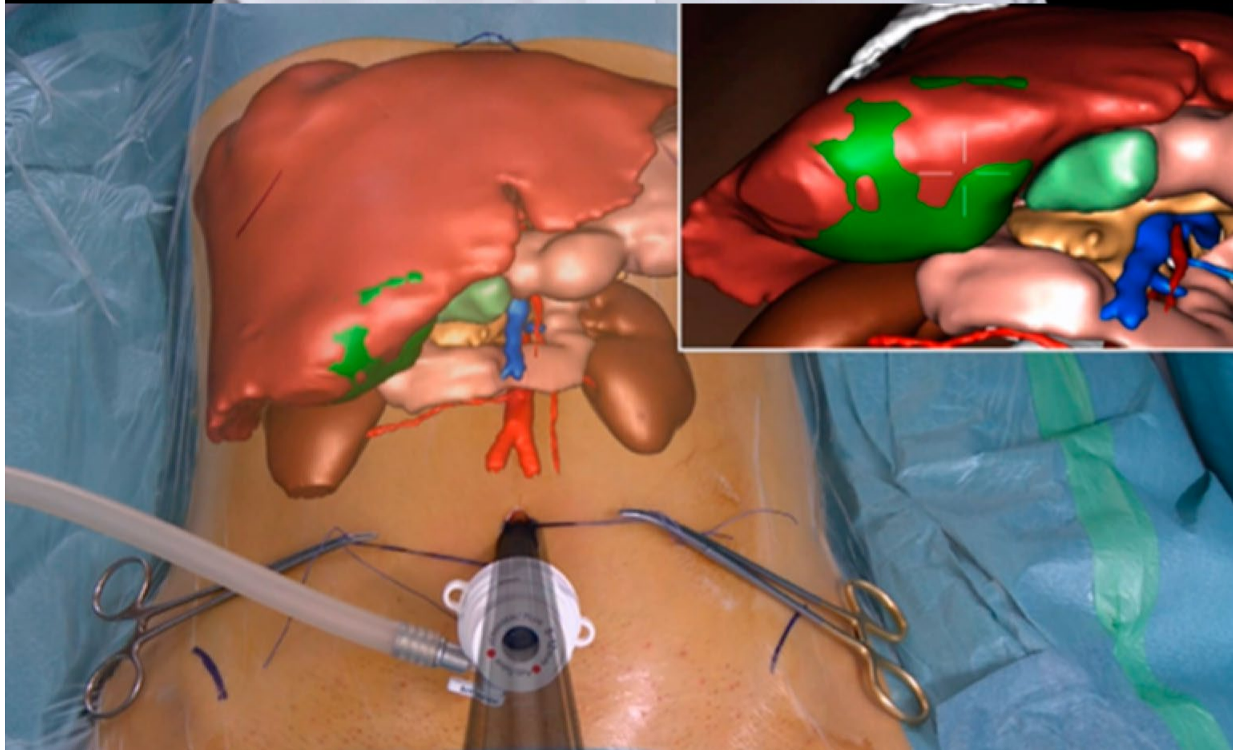
• Surgeons from different locations can train together in a **shared virtual operating room (OR)**.

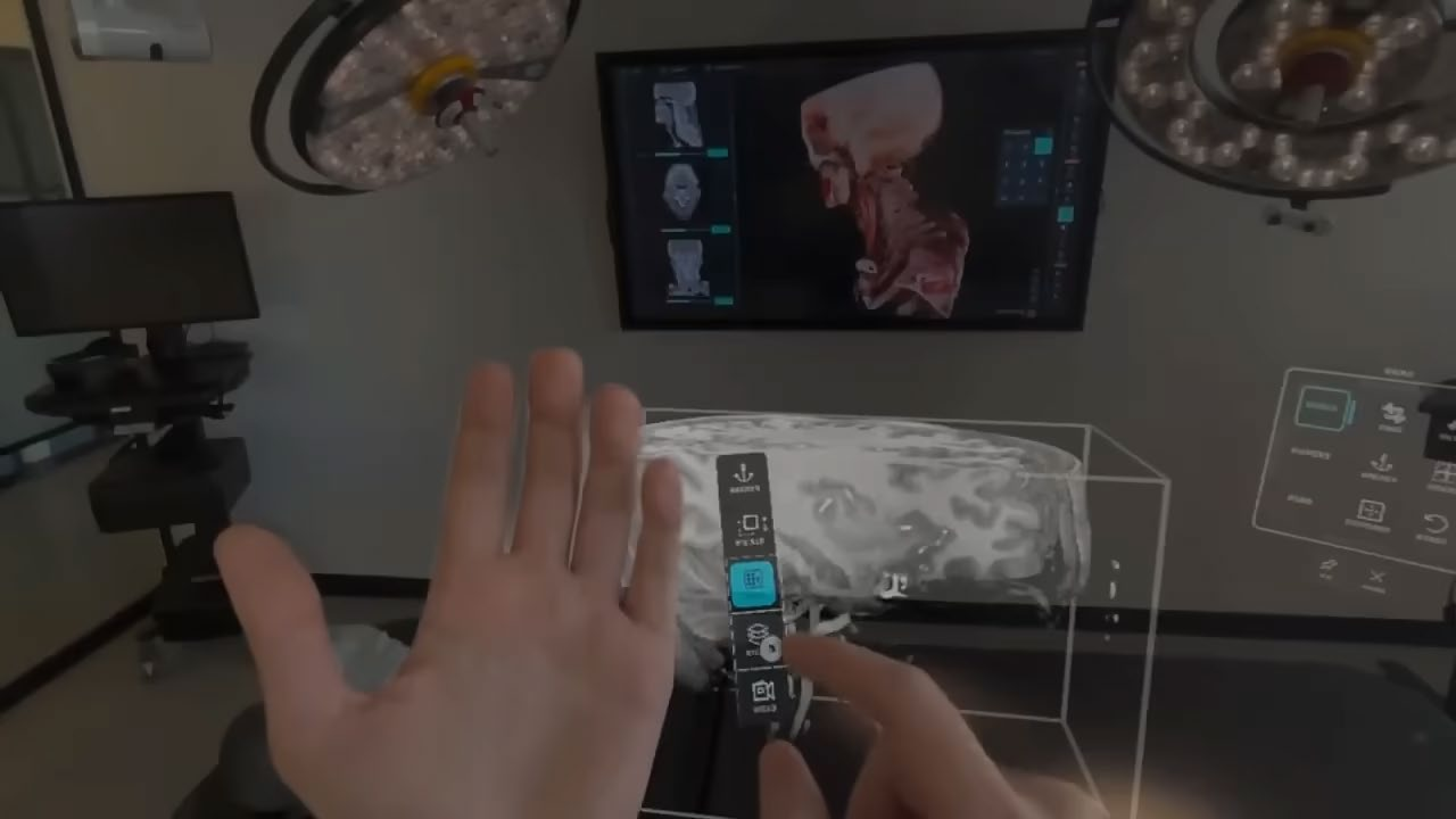
• Examples: **Osso VR, Touch Surgery** platforms.

Augmented Reality (AR)

- **Overlays** digital elements onto the real world without replacing it.
- Works with **AR glasses** (e.g., Apple Vision Pro).
- Subjects may **interact** with digital objects

Real world with digital overlays





Augmented Reality (AR) in Surgical Training

✓ **Overlaying Digital Information on Patients**

• AR projects **3D anatomical models, CT scans, and MRI data** onto real patients.

• Helps surgeons visualize organs, blood vessels, and tumors **before making incisions**.

✓ **Guided Surgery & Real-Time Navigation**

• AR-assisted **navigation systems** provide real-time guidance during operations.

✓ **Teaching & Supervision**

• Students can view **live surgeries with AR annotations** highlighting important structures.

Mixed Reality (MR)

- Combines aspects of VR and AR, allowing **advanced interaction** between digital objects and the real world.
- Digital objects can respond to the physical environment
- Requires **advanced hardware** like HoloLens or MR headsets.

Real and virtual worlds interacting

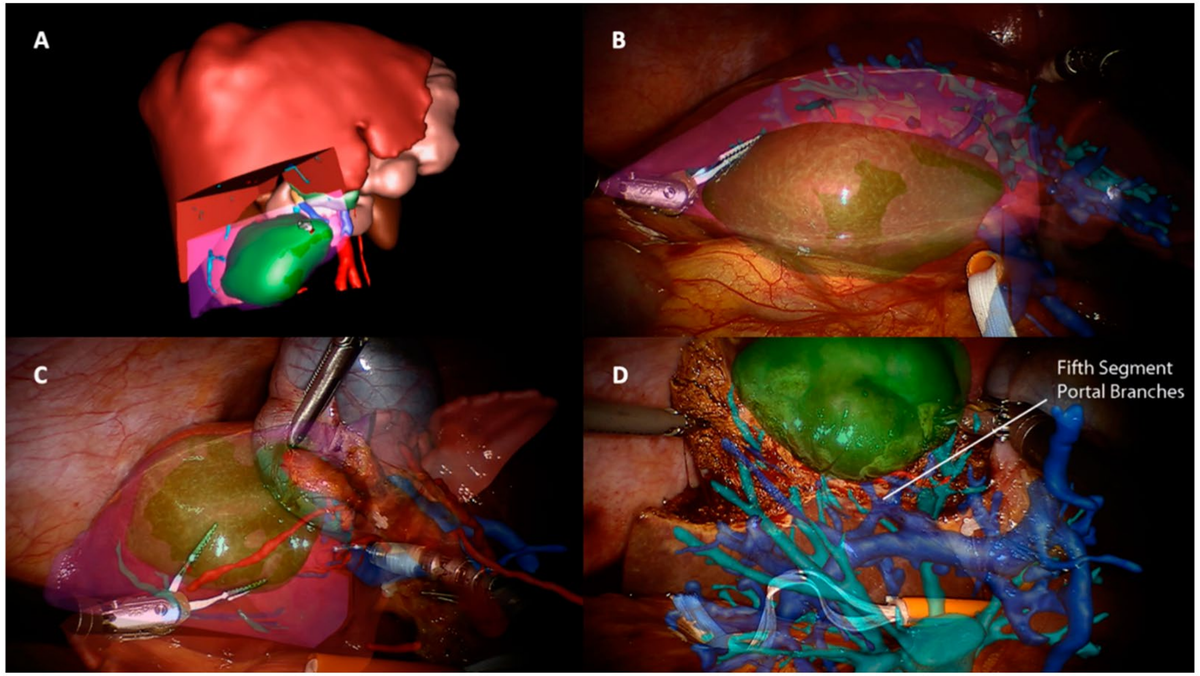
Mixed Reality (MR) in Surgical Training

✓ **Interaction with Virtual and Real Objects**

• Surgeons can **manipulate holographic 3D organs** and practice on **hyper-realistic simulations**.

✓ **Preoperative Planning & Personalized Surgery**

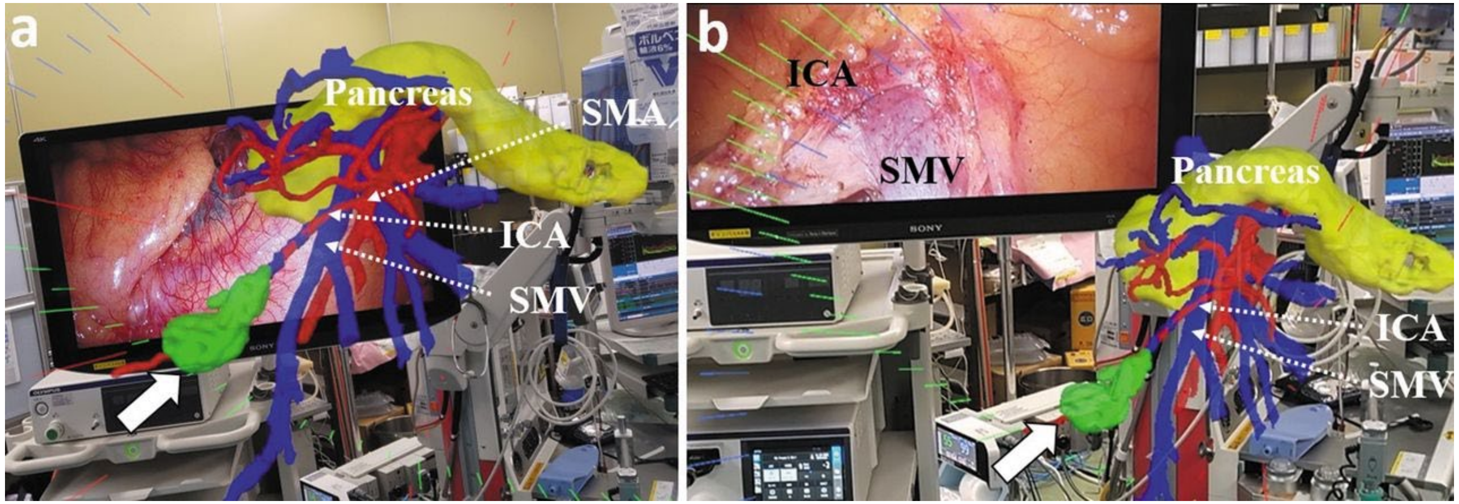
• MR enables **patient-specific surgical planning** by creating **customized 3D reconstructions** of organs.



✓ **Remote Assistance & Telemedicine**

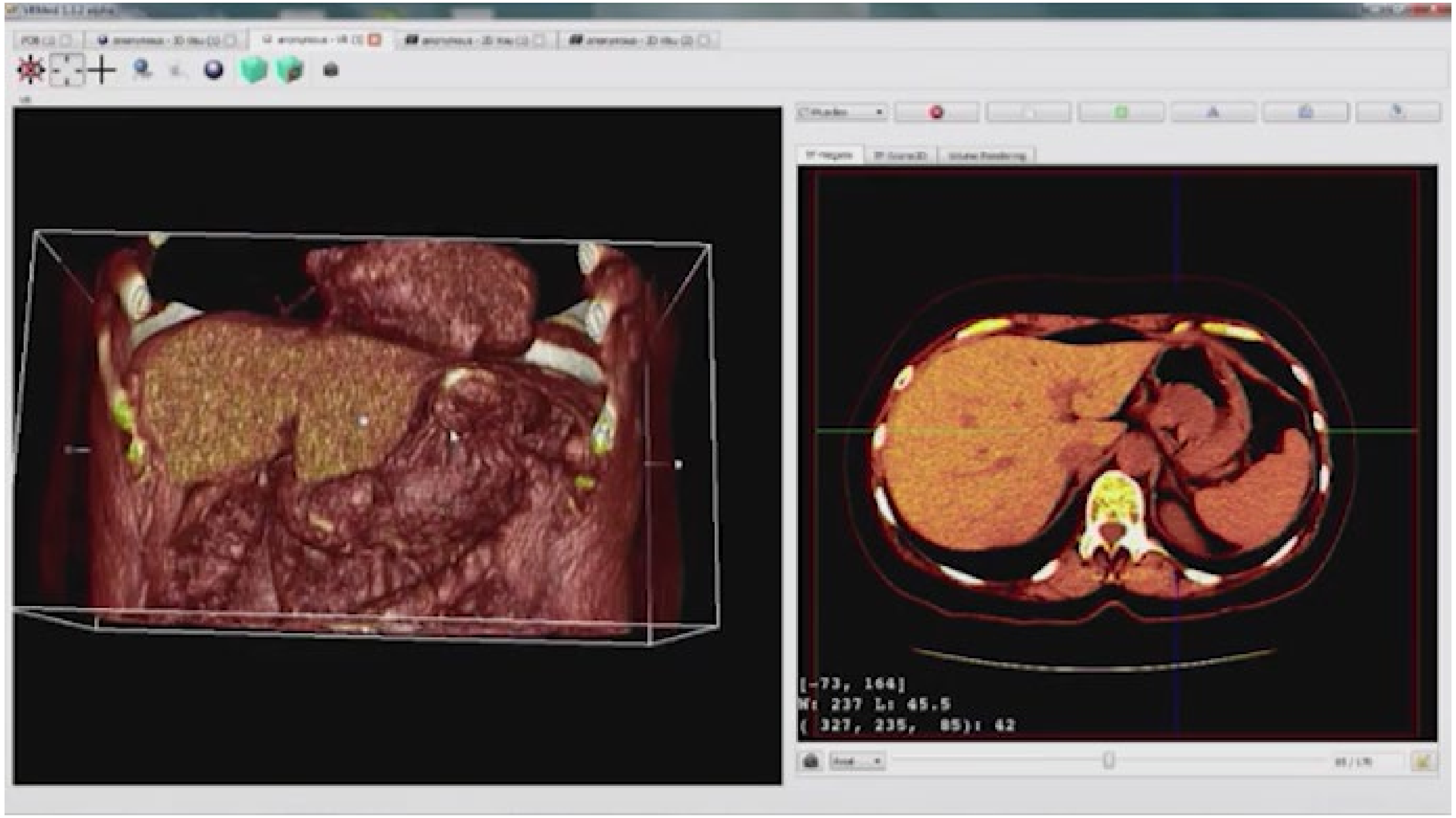
• Experts can **join surgeries remotely**, guiding surgeons in real time using **holographic annotations**.

• Helps in **global surgical training programs**.



XR Technologies development: personalized surgery

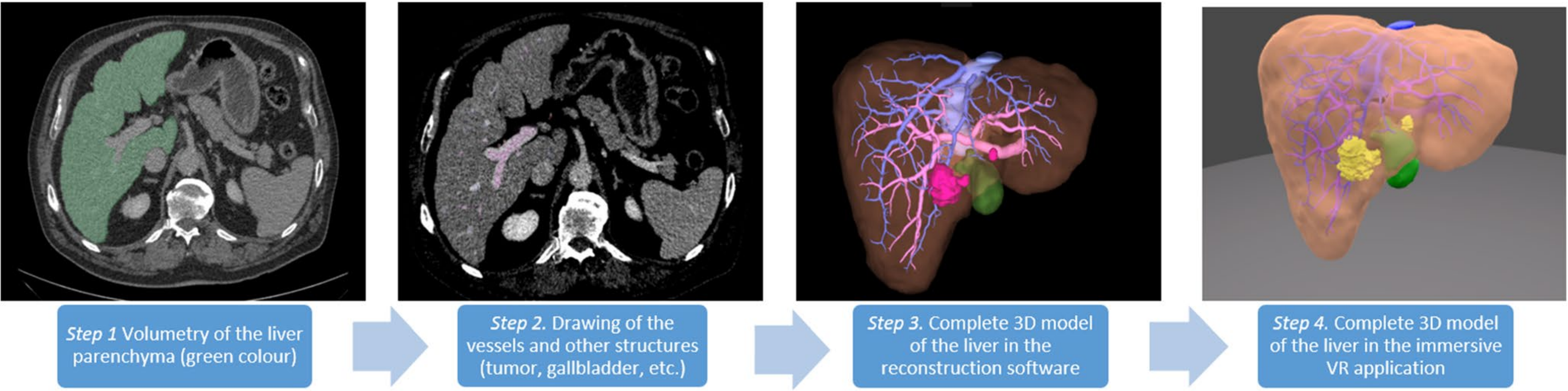
STEP 1: IMAGING ACQUISITION



- <u>High-resolution images</u> are captured using **CT scans, MRI, or ultrasound**.
- These images provide a **detailed view** of the patient's anatomy

XR Technologies development: personalized surgery

STEP 2: VIRTUAL 3D-MODEL OF THE PATIENT/ORGAN



Langenbeck's Archives of Surgery (2021) 406:911–915
https://doi.org/10.1007/s00423-021-02127-7

HOW-I-DO-IT ARTICLES

Check for updates

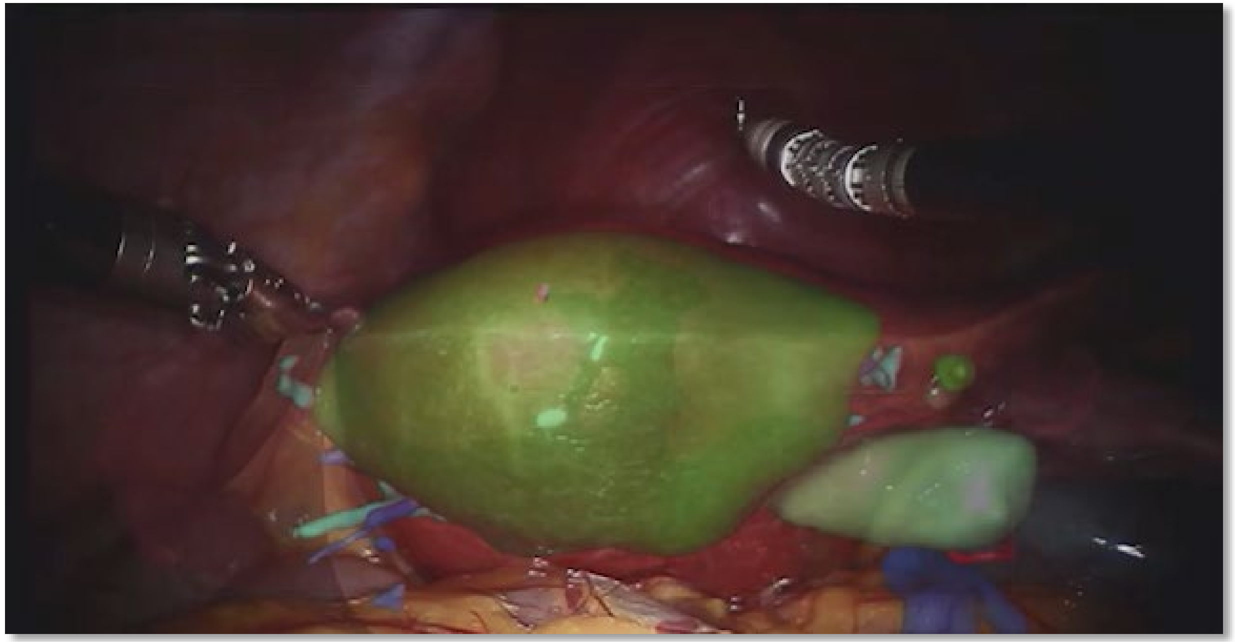
Using virtual 3D-models in surgical planning: workflow of an immersive virtual reality application in liver surgery

Christian Boedecker[1] · Florentine Huettl[1] · Patrick Saalfeld[2] · Markus Paschold[1] · Werner Kneist[1] · Janine Baumgart[1] · Bernhard Preim[2] · Christian Hansen[2] · Hauke Lang[1] · Tobias Huber[1]

- The 2D scan images are processed using **computer vision and AI algorithms** to generate **3D models**.
- **Segmentation techniques** are used to isolate different structures (e.g., bones, blood vessels, tumors).

XR Technologies development: personalized surgery

STEP 3: FUSION VIRTUAL MODEL – REALITY



- The 3D models are **registered** to the patient's real-world position using:
  - **Optical tracking systems** (cameras tracking fiducial markers)
  - **Electromagnetic tracking** (sensors attached to surgical tools)
  - **AI-based landmark recognition** (detecting key anatomical points)
- The processed images are **overlaid onto the surgeon's field of view** via:
  - **AR headsets** (e.g., Microsoft HoloLens, Magic Leap)
  - **Surgical microscopes with AR integration**
  - **Tablet-based or monitor-based AR systems**
- Surgeons can see a virtual guide aligned with the patient's body.

Key XR Applications in Minimally Invasive Surgery

A. ENHANCED VISUALIZATION OF INTERNAL STRUCTURES

- Helps surgeons **"see through" organs** and avoid damaging critical structures (blood vessels, nerves etc.)

B. AUGMENTED SURGICAL NAVIGATION & GUIDANCE

- **Real-time tracking of instruments and anatomical landmarks**.
- Overlays guides onto the screen to **show optimal incision points, pathways for instruments, or cutting lines**.

C. XR-GUIDED TUMOR RESECTION

- XR assists in **identifying tumor margins**, helping ensure complete removal while sparing healthy tissue.

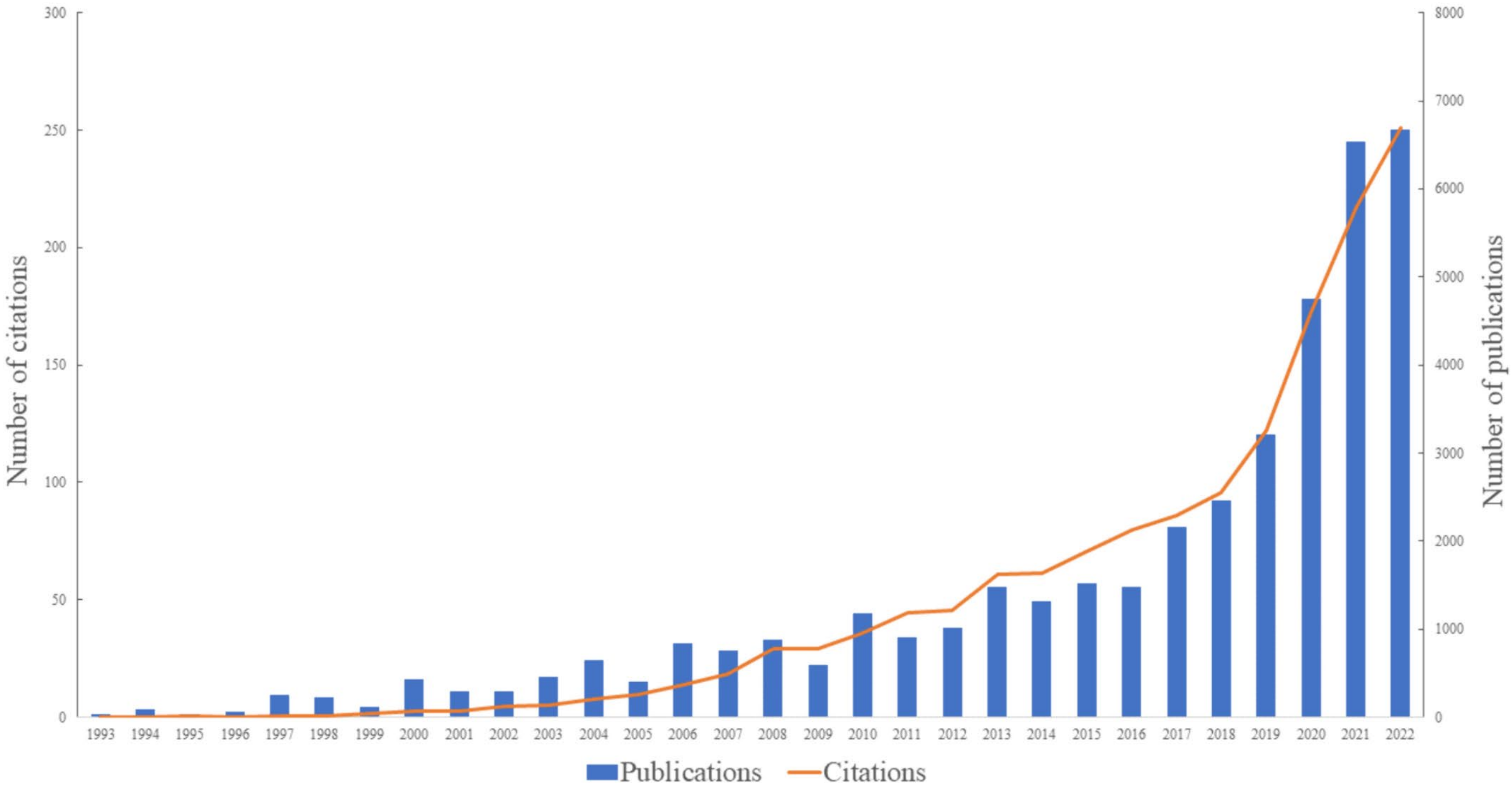
D. ROBOTIC-ASSISTED LAPAROSCOPIC SURGERY (AR + ROBOTICS)

- AR integrates with **robotic surgery platforms like da Vinci Surgical System**, allowing surgeons to see enhanced 3D models on the robotic console.
- **Improves precision**

E. TRAINING AND SIMULATION FOR SURGEONS

- XR is used in **laparoscopic surgical training** to simulate real-life scenarios.
- Medical trainees can **practice in a virtual AR-enhanced environment** before performing live surgeries.

The number of publications in the field of XR in medical education has surged in parallel with the rapid advancements in technology over the past years.



Surgery Open Science 20 (2024) 151–155

Contents lists available at ScienceDirect

Surgery Open Science

journal homepage: www.journals.elsevier.com/surgery-open-science

SURGERY
OPEN SCIENCE

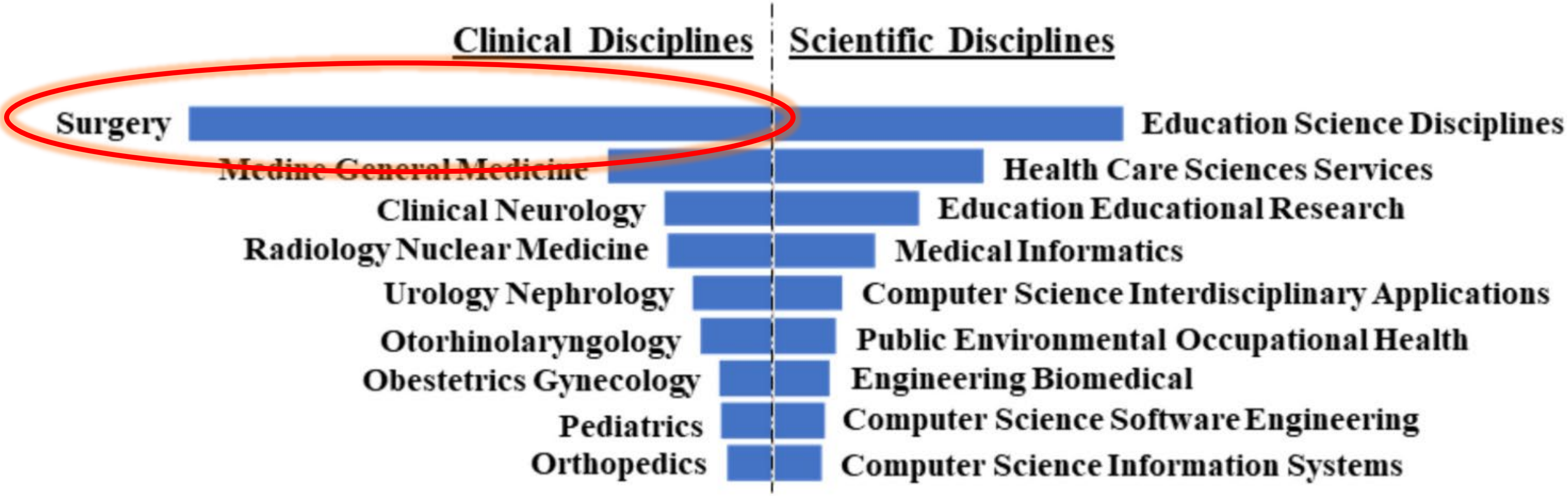
Research Paper

Revolutionizing medical education: Surgery takes the lead in virtual reality research

M.A. Wolf[a,*], M. Mergen[b], P. Winter[a], S. Landgraeber[a], P. Orth[a]

[a] Department of Orthopedics, Saarland University, Kirrberger Straße 100, 66421 Homburg, Saarland, Germany
[b] Department of Pediatric Oncology and Hematology, Saarland University, Kirrberger Straße 100, 66421 Homburg, Saarland, Germany

Ranking of the clinical and scientific disciplines most involved in the publication on the use of VR in medical education.



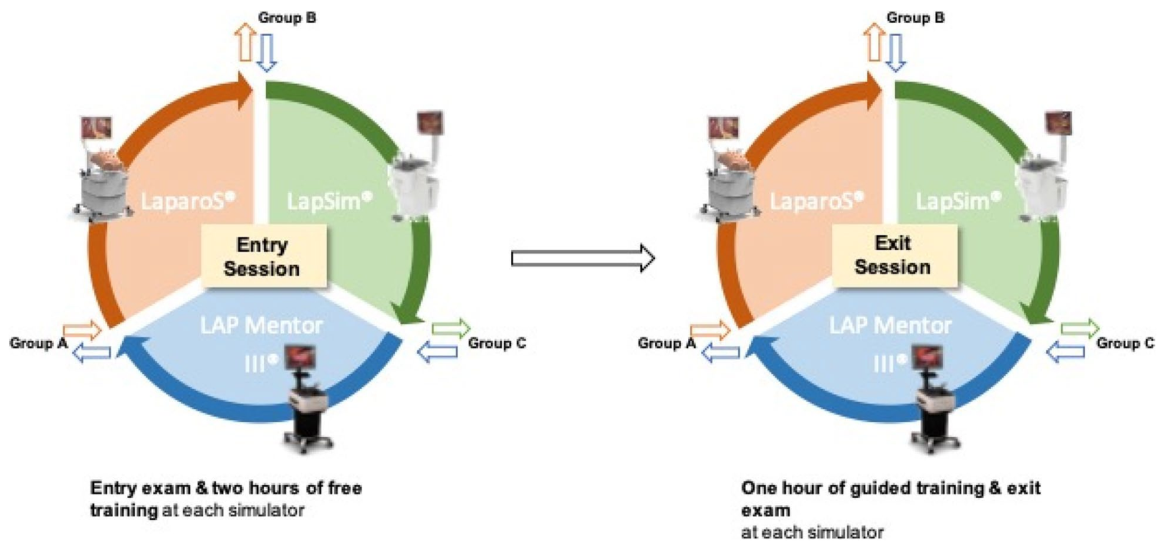
Sparn et al. BMC Medical Education (2024) 24:589
https://doi.org/10.1186/s12909-024-05574-0

BMC Medical Education

RESEARCH | Open Access

Virtual reality simulation training in laparoscopic surgery – does it really matter, what simulator to use? Results of a cross-sectional study

Moritz B. Sparn[1], Hugo Teixeira[2], Dimitrios Chatziisaak[1], Bruno Schmied[1], Dieter Hahnloser[2*] and Stephan Bischofberger[1]



3 different simulators: LaparoS (VirtaMed), LapSim (Surgical Science) and LapMentor III (Simbionix)

8 comparable exercises, training the same basic laparoscopic skills

- VRST leads to **significant improvement** already in short periods of time and with less-than-ideal training modalities, regardless of the sequence in which simulators were used.
- All VRS **trained efficiently the same basic surgery skills**, regardless of the sequence or simulator used.
- VRST **should be incorporated** in all surgical training programs.
- However, **standardized and validated outcome metrics** should be implemented to reliably measure proficiency and performance of trainees.

Surgical Endoscopy (2025) 39:307–318
https://doi.org/10.1007/s00464-024-11387-5

Augmented reality for basic skills training in laparoscopic surgery: a systematic review and meta-analysis

Jian Xiong[1,2] · Xiaoqin Dai[3] · Yuyang Zhang[4] · Xingchao Liu[2] · Xiyuan Zhou[1]

- A total of **12 studies** involving **434 participants**
- The laparoscopic procedures included were all **cholecystectomies**, with three studies utilizing the same XR system, iSurgeon.

AR technology **significantly improves laparoscopic training outcomes for medical students and junior physicians**.

Participants using AR achieved higher scores, **reduced training time**, and experienced lower cognitive load compared to conventional methods.

AR technology also **enhances technical skills,** boosts task efficiency, and reduces reliance on instructors, making it particularly valuable in resource-constrained environments.

However, **standardized protocols** and improved AR systems re needed. **Long-term follow-up studies** and **cost-effectiveness analyses** are crucial to fully realize AR's potential in both medical education and clinical practice.

Potential Applications of XR in Colorectal Surgery

Pre-operative Planning

VR allows surgeons to **visualize the patient's anatomy** in 3D and and plan the surgical approach.

Intraoperative Guidance

AR overlays anatomical information on the patient's body during surgery, improving precision and accuracy.

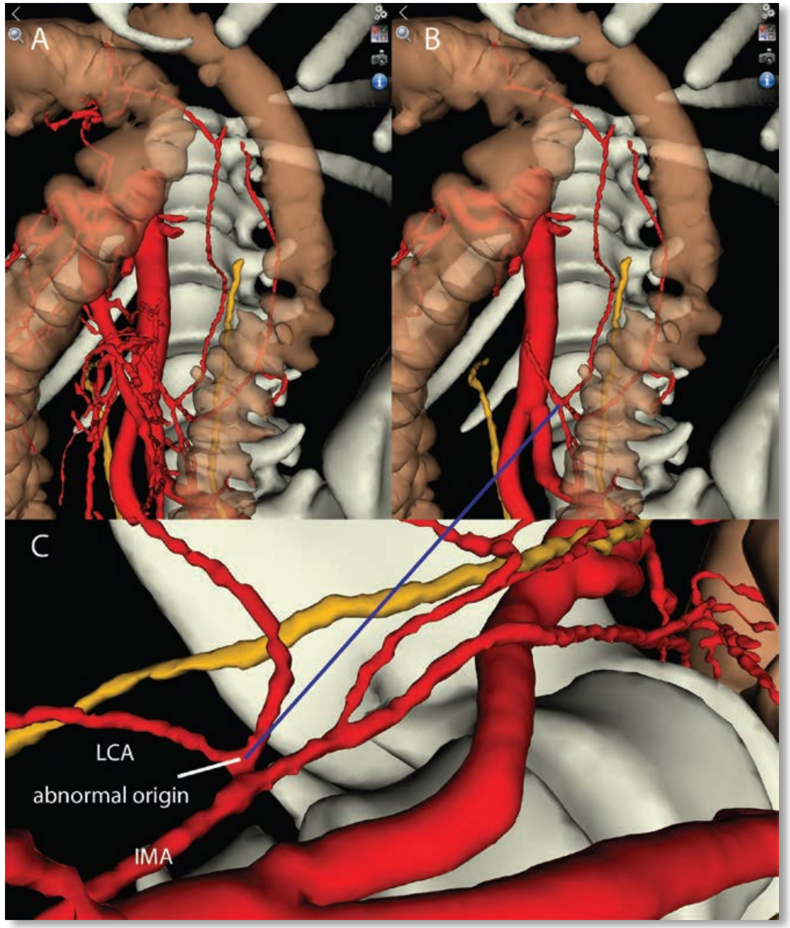
Surgical Skills Training

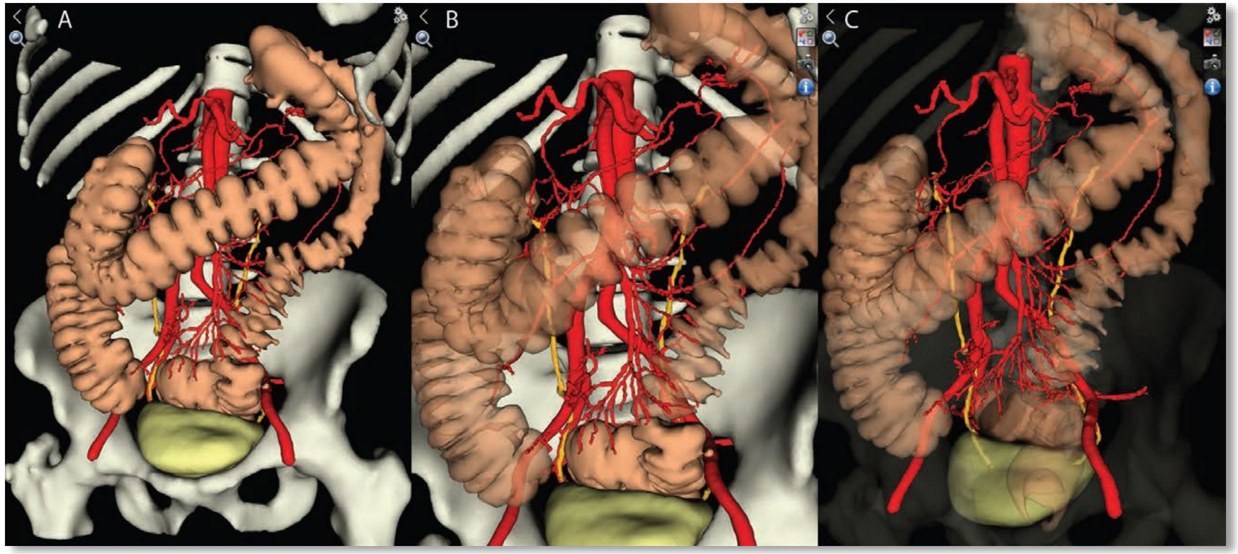
MR provides realistic simulations for surgeons to practice **complex procedures**, enhancing their skills and confidence.

Virtual Reality Exploration and Planning for Precision Colorectal Surgery

Ludovica Guerriero, M.D.[1,2] • Giuseppe Quero, M.D.[2]
Michele Diana, M.D., Ph.D.[2,3] Luc Soler, Ph.D.[2,3] • Vincent Agnus, Ph.D.[3]
Jacques Marescaux, M.D., F.R.C.S. (Hon.), F.J.S.E.S. (Hon.), A.P.S.A.[2,3]
Francesco Corcione, M.D.[1]

- Preoperative planning
- Vascular identification
- Vascular anomalies
- Tumor location
- Infiltration






CIR ESP. 2024;102(s1):s36–s44

CIRUGÍA ESPAÑOLA

www.elsevier.es/cirugia

Special article

The use of mixed reality in the preoperative planning of colorectal surgery: Preliminary experience with a narrative review

Umberto Bracale[a], Biancamaria Iacone[b,], Anna Tedesco[b], Antonio Gargiulo[b], Maria Michela Di Nuzzo[b], Daniele Sannino[b], Salvatore Tramontano[a], Francesco Corcione[b]*

[a] Department of Medicine, Surgery and Dentistry, University of Salerno, 84084 Salerno, Italy
[b] Department of Public Health, University of Naples Federico II, 80131 Naples, Italy

- **Better visualization**, particularly in patients undergoing **right hemicolectomy**, where there was greater **anatomical variability**.

- **Senior surgeons** exhibited significantly **lower scores** compared to junior surgeons in terms of workload, mental demands, time required, and effort.

- The holograms were very useful to **identify the lack of left colic artery and very high splenic flexure** in some cases

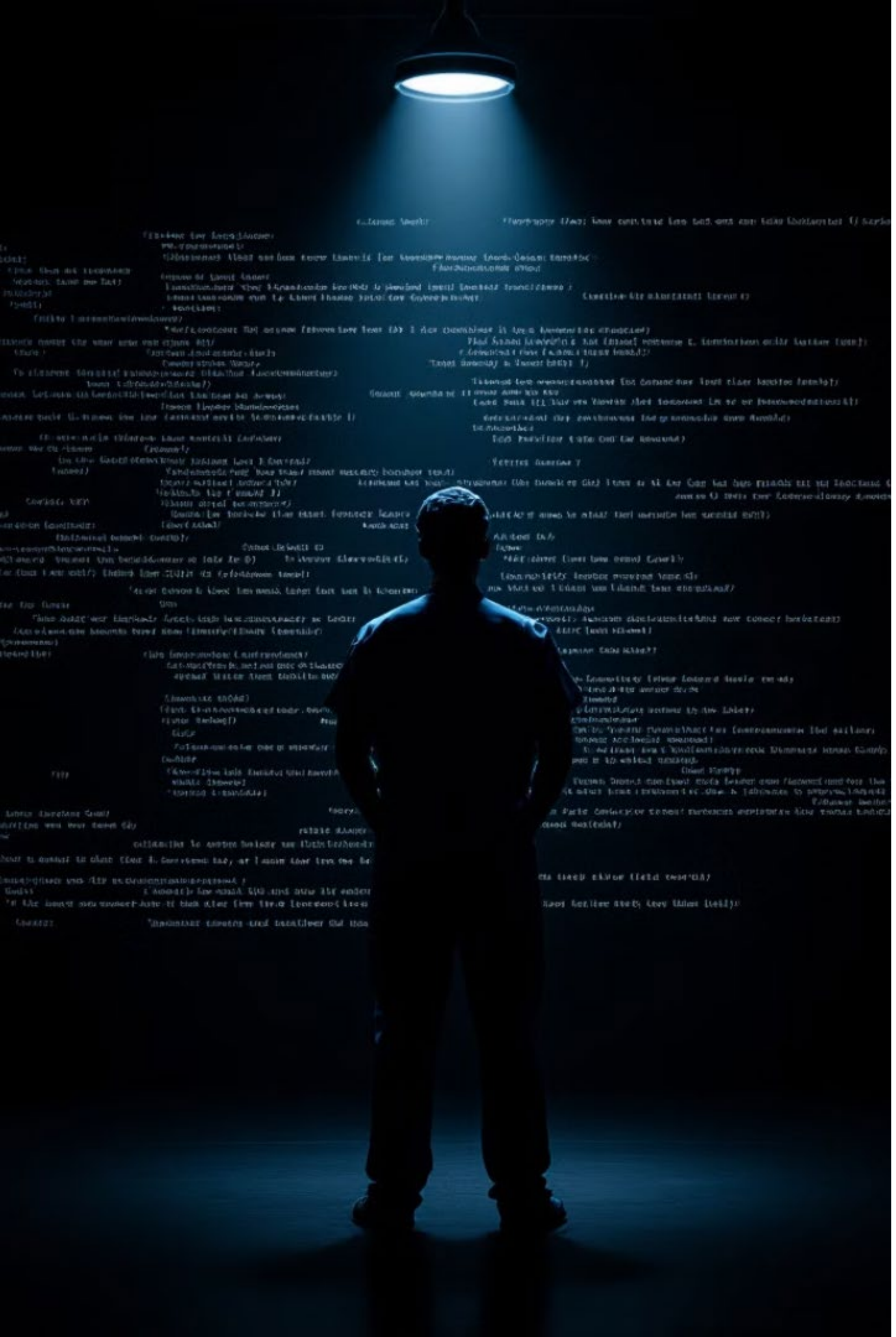
Benefits of XR in Laparoscopic Surgery

✅ **Increased Precision** – Surgeons get real-time augmented visuals, improving accuracy.

✅ **Reduced Risk of Complications** – Avoids accidental injuries to nerves and blood vessels.

✅ **Shorter Surgery Time** – Better visualization reduces operation duration.

✅ **Improved Training & Education** – Allows junior surgeons to learn in a simulated VR environment.



Challenges and Limitations of XR

1

COST

The high cost of XR technology can be a barrier to widespread adoption.

2

TECHNICAL COMPLEXITY

XR technology requires specialized expertise and technical infrastructure.

3

LEGAL APPROVAL

XR applications in surgery require rigorous testing and regulatory approval.