INTERACTIVE SURGERY TECHNICAL DOCUMENT

IRIS™ : a new Oculus immersive device for remote interactive collaboration of surgical experts

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submitted: Apr 16, 2026, accepted: Apr 25, 2026, EPub Ahead of Print: Apr 29, 2026, published: Apr 30, 2026
Conflict of interest: None

DOI: 10.24019/jtavr.255 - Corresponding author:Prof. Jean François Uhl, jeanfrancois.uhl@gmail.com

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Abstract Background: Virtual reality and artificial intelligence are transforming all areas of medicine, particularly 3D anatomical imaging and surgery. Training and simulation are used daily in endoscopy and surgery, and are always image-guided, providing accurate 3D models thanks to AI-powered automatic anatomical segmentation. Fields of use: surgical specialties with high anatomical complexity: Surgical oncology: resection margins, tumor–vessel relationships; Neurosurgery: planning craniotomies and brain tumor resections; Maxillofacial surgery: facial reconstructions and orthodontic planning; Orofacial surgery and implantology; Traumatology: complex fractures, bone deformities, prosthetic surgery; Thoracic surgery: lung resections, minimally invasive cardiac surgery; Hepatic and lung surgery: preoperative planning for segmentectomy Objective: The new IRIS(TM) Oculus device enables interactive and collaborative remote connections for discussing complex anatomical surgical cases using an immersive reality headset (Meta Quest 3S). This new image-guided technology is set to transform surgical planning! Benefits in education, simulation and training surgery: The system includes a platform (Iris browser) and an Oculus(TM) app that enables multiple surgeons to collaborate on discussing the 3D anatomy of the same patient before making surgical decisions based on CT Angioscan DICOM data. A dedicated server automatically reconstructs 3D segmented models using an advanced algorithm to enhance anatomical accuracy and segmentation quality. IRIS is a research prototype for surgeons; it is not yet a certified medical device. Conclusion: IRIS(TM) represents a groundbreaking advancement in immersive medicine, particularly in surgery and oncology, where a multidisciplinary approach is essential. It automates the segmentation process and enables real-time remote collaboration, thereby enhancing clinical decision-making and fostering team coordination. IRIS also supports enhanced pre-surgical planning and interdisciplinary communication, and serves as an excellent educational tool for surgical simulation, AI-assisted segmentation, and anatomy learning.

Keywords 3D Anatomy, Immersive Reality, Surgical Planning, automatic segmentation, remote collaboration.

1. Introduction

Virtual reality (VR) and artificial intelligence (AI) are transforming modern medicine at an astonishing rate with regard to anatomical visualization and surgical planning, particularly in patients with complex anatomy.

Nicolas Ayache's pioneering concept[1-3] of personalized digital -patients (or digital avatars) has revolutionized medical practices across all specialties thanks to the creation of realistic 3D models of the human body.

Among the emerging technologies, extended reality (XR) and immersive virtual reality (IVR) offer unparalleled potential for collaborative, remote, image-guided decision-making.

The IRIS "*Immersive Remote Interaction for* Surgery" platform was developed to bridge the gap between DICOM-based imaging and expert-level, multidisciplinary surgical planning[4]. It enables DICOM data to be downloaded and displayed in a remote immersive reality environment via a Meta3S Oculus© headset[5] .

2. Background and Rationale

High-quality anatomical segmentation is fundamental to modern oncological diagnostics, treatment planning, and patient education.

Traditional 2D imaging can limit the ability to fully assess complex anatomical relationships, which is particularly problematic in oncology, where the extent of the tumor and its relationship with surrounding structures determine the therapeutic strategy.

Fortunately, automated segmentation algorithms, particularly those that use deep learning, can now generate robust 3D models from DICOM data. Integrating these models into immersive VR environments enables new approaches to visualizing cases and collaborative remote planning.
The main benefits of 3D imaging in surgery:
It improves diagnostic accuracy: 3D models allow for an accurate study of the patient's anatomy.

It also enables personalized surgical planning[4]: 3D models can simulate surgical procedures, helping to better understand each patient's specific anatomy and enabling the planning of the optimal surgical approach. This reduces intraoperative uncertainties and improves safety and outcomes[6-9].

This approach offers better sensitivity and specificity than 2D methods and enables remote educational surgeries[10,11] to discuss strategies.

For patient education, 3D models help patients better understand their condition and proposed treatments, thereby increasing their engagement in the care process.

Benefits of multidisciplinary and remote medical collaboration:

3D imaging enables more effective collaboration between specialists, such as radiologists, surgeons, and oncologists. 3D models can be shared via a web server to facilitate remote consultations and the exchange of information among healthcare professionals.

Integration with artificial intelligence enables more accurate analysis of 3D images, helping to improve diagnoses and decision-making.

3. Device and workflow

a. The immersive reality device used is the Oculus-®-mask Meta 3S (Fig 1)

Characteristics

- Screen type: Single LCD, shared for both eyes.
- Resolution: 1832 × 1920 pixels per eye (# 3.5 megapixels total).
- Lenses: Fresnel (not pancake-style like the Quest 3).
- Field of view: # 96° horizontal, # 90° vertical
- Refresh rate: 90 to 120 Hz depending on mode.
- Hardware performance:
- SoC: Qualcomm Snapdragon XR2 Gen 2. RAM: 8 GB. Internal storage: 128 GB.



Fig 1 - Oculus-®-mask Meta 3S

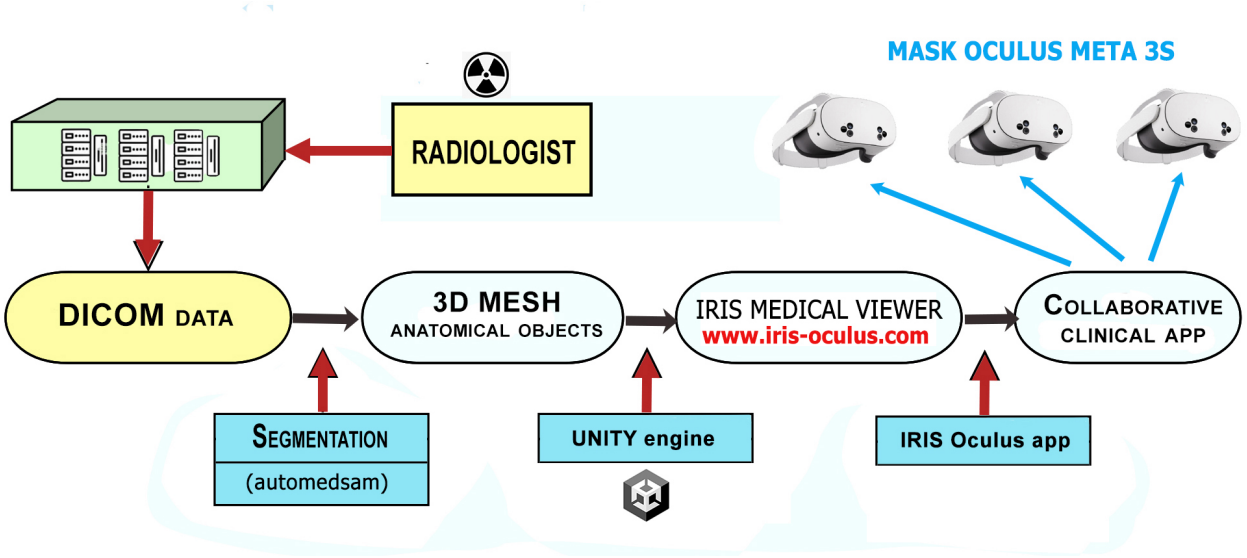


Fig 2 - Iris workflow DICOM DATA→ Segmentation→ 3D modeling→ Unity engine→ VR integration (IRIS)→ Oculus Immersive App

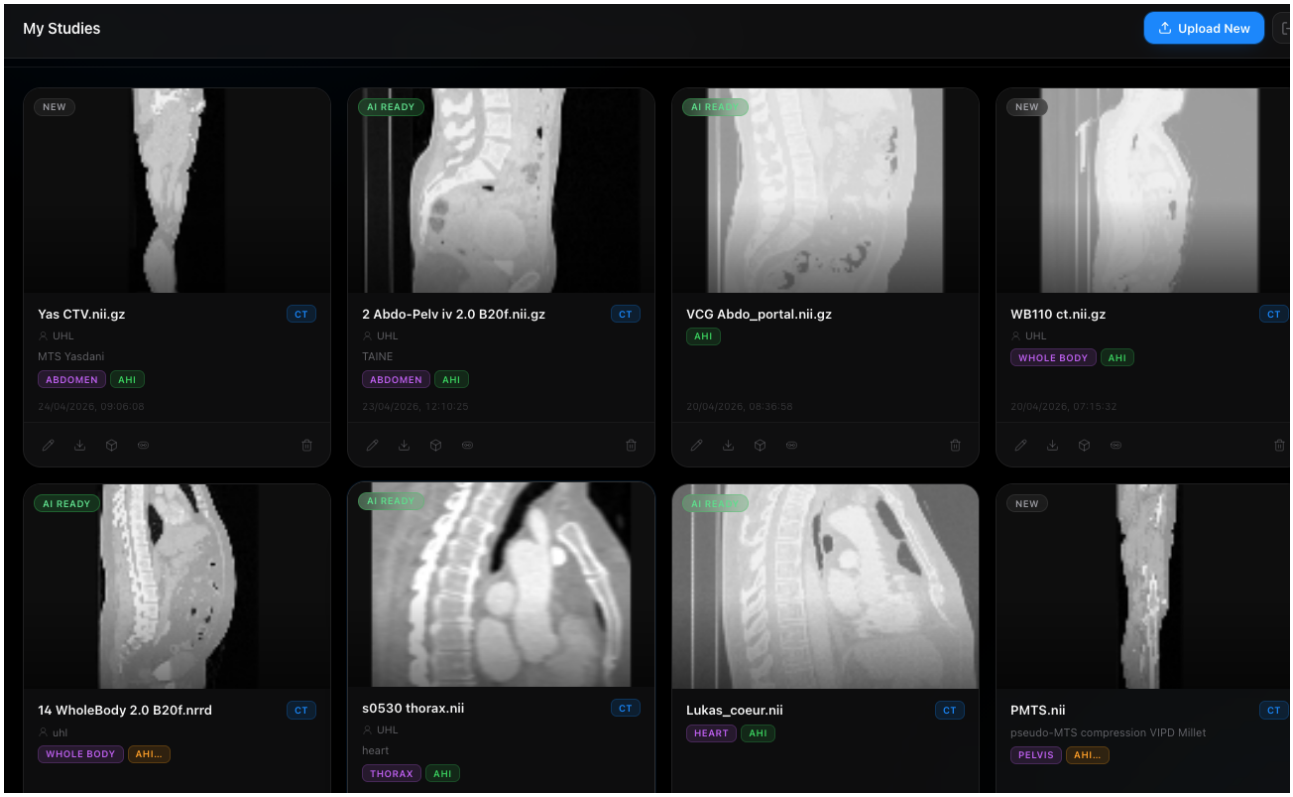


Fig 3 - Web interface of the Iris medical viewer. The browser displays the studies available on the web server.

b. IRIS Workflow from DICOM imaging to Immersive VR (Fig 2)

The IRIS® platform (Iris Medical Viewer) offers a seamless pipeline from patient imaging to collaborative immersive review.

This process involves 4 main steps

1. **Step 1: Data layer - ingestion, de-identification and storage via the Iris Medical** Viewer[12] is available through a GPU server (https://www.iris-oculus.com) operated by the team from Instituto Superior Técnico (University of Lisbon) on an AWS cloud back-end (region us-east-1).

After creating a personal user account, clinicians can upload anonymized patient DICOM images to the server (see the "Upload New" button in Fig 3). Files are transferred directly from the browser to Amazon S3 via pre-signed URLs, which ensures fast transfers of multi-gigabyte studies and prevents long-running GPU workers from being exposed to the public internet.

A search filter is available by name, protocol, and region ("search studies").

2. **Step 2: Processing layer - automatic anatomical segmentation** is then performed automatically via the AutoMedSAM[13]algorithm, a cutting-edge AI algorithm based on Meta AI's Segment Anything Model[14] (SAM) and optimized through diffusion-based auto-prompting for medical images.

The user must select one of the three main algorithms available: whole body (total segmentator), brain, and dental segmentation. *Previous or additional segmentation performed separately using 3dslicer®* can also be imported in complex cases to supplement the AI-generated segmentation, particularly to achieve a more accurate representation of the vessel anatomy.

The 3DSlicer® ecosystem[12] (Fig 4) is a cross-platform package, but certain requirements on the graphics system, such as OpenGL drivers, must be met to support accelerated rendering. Its dependency libraries are portable across platforms and are distributed under compatible licenses. These dependencies are part of the NA-MIC Kit. Slicer itself consists of the main application framework (core) and plugins (modules). Custom functionality is implemented by adding external modules (Slicer extensions).

An example is provided here of whole-body segmentation using the Totalsegmentator® Algorithm[15] also used with 3Dslicer®.(Fig 5)

3. **Step 3: Presentation layer - geometric reconstruction and web-based review**. Once the label map is produced, each anatomical structure is converted to a triangular surface using the marching-cubes algorithm (scikit-image). The raw mesh is then cleaned (removal of duplicate vertices and degenerate faces), smoothed with a volume-preserving Taubin filter to soften the characteristic staircase artifacts of voxel-based iso-surfacing, and decimated using a quadric-error metric (default target: 10% of the original triangle count).

This reduces a typical thoracic mesh from several hundred megabytes to a few megabytes, so that it can be streamed over the network and rendered interactively in the web viewer and on the Oculus headset. Structures are grouped into eleven physiological systems (arteries, veins, heart, digestive, endocrine, muscular, nervous, reproductive, respiratory, skeletal, urinary) with a system-specific color palette; for dental studies, individual teeth are colored by FDI number. The resulting models become automatically available on the Iris medical viewer.

Meshes are then accessible via the Iris web viewer, which displays a list of processed studies (see Fig 2). Filters and file selection are available by name, protocol, or region. Clicking on a file downloads and displays the 2D and 3D images.

Fig 6 shows the screen interface after selecting a patient with the 3D view. Using the 'System' menu at the bottom of the screen, the user can choose which anatomical structures to display or hide. (Here, 11 systems are displayed: Arteries, veins, digestive, endocrine, heart, muscular, nervous, reproductive, respiratory, skeletal, and urinary).

4. **Step 4: Collaboration layer - immersive multi-user VR integration**. Once the meshes are validated in the web viewer, the server generates a one-time 5-digit access code (valid for 24 hours) that the clinician enters into the IRIS Unity application running on the Meta Quest 3S headset (Fig 1). The code also serves as a room identifier: every participant who enters it joins the same shared session, and the back-end keeps the state of the meshes (position, rotation, scale, visible systems, clipping planes, annotations) synchronized in real time via a WebSocket channel.

Up to four remote users can therefore discuss the same case simultaneously, as if they were standing around a single holographic patient, regardless of their physical location. When the session ends, the access code is invalidated and the shared state is discarded, so that no patient-derived geometry remains on the collaboration layer beyond the meeting itself.

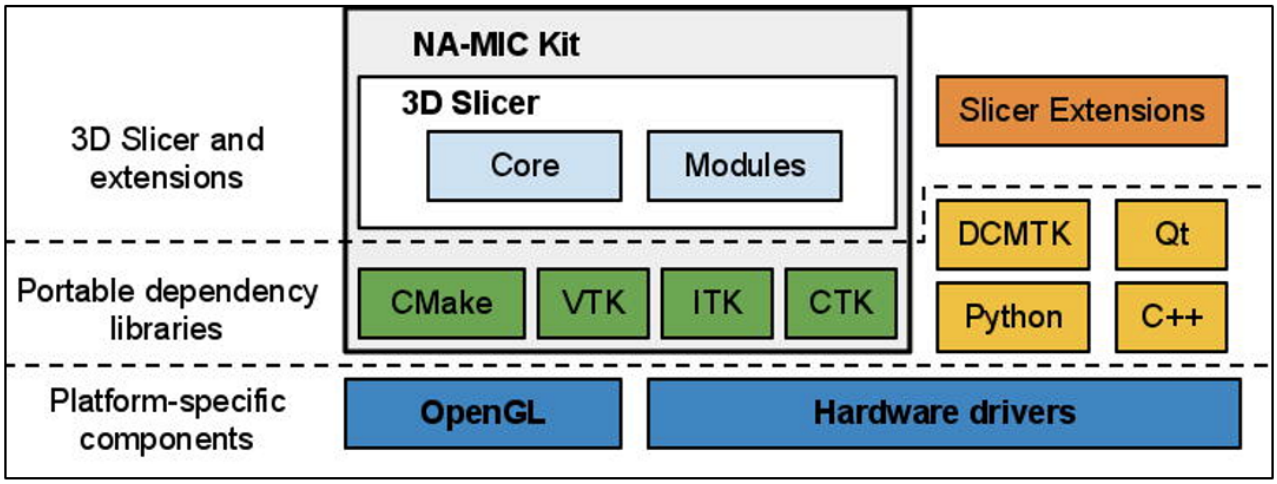


Fig 4 - 3D Slicer® ecosystem is a cross-platform package; Slicer itself consists of the main application framework (core) and plugins (extension modules).

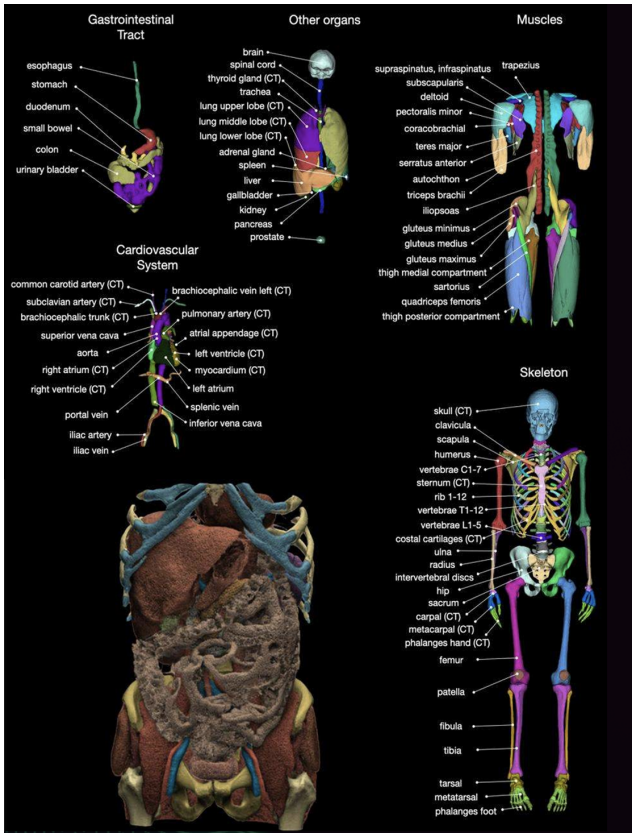


Fig 5 - Totalsegmentator® automatic segmentation algorithm producing 120 anatomical elements.

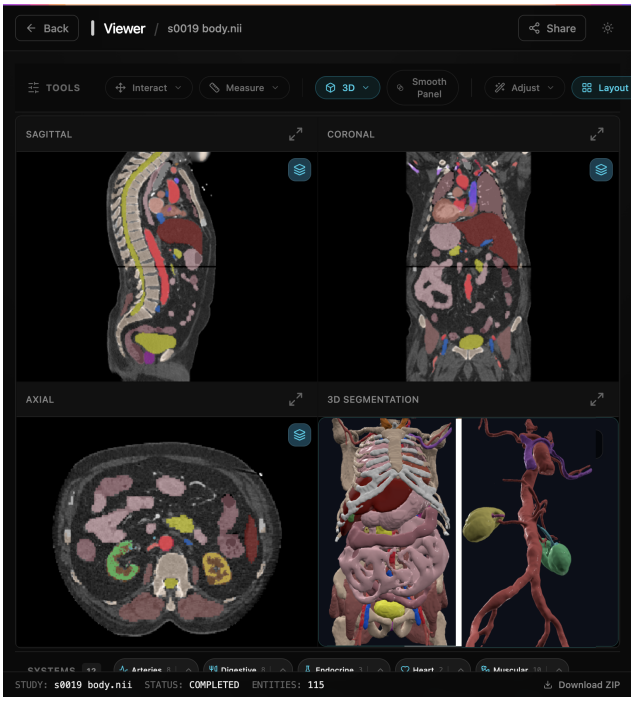


Fig 6 - This is the screen interface of the Iris viewer (MPR + 3D segmentation) after selecting a file with the available tools (interact, measure, 3D, smooth, adjust, and view options). The systems to be displayed can be selected at the bottom of the screen. In the bottom right corner, both AI and manual segmentations are displayed.

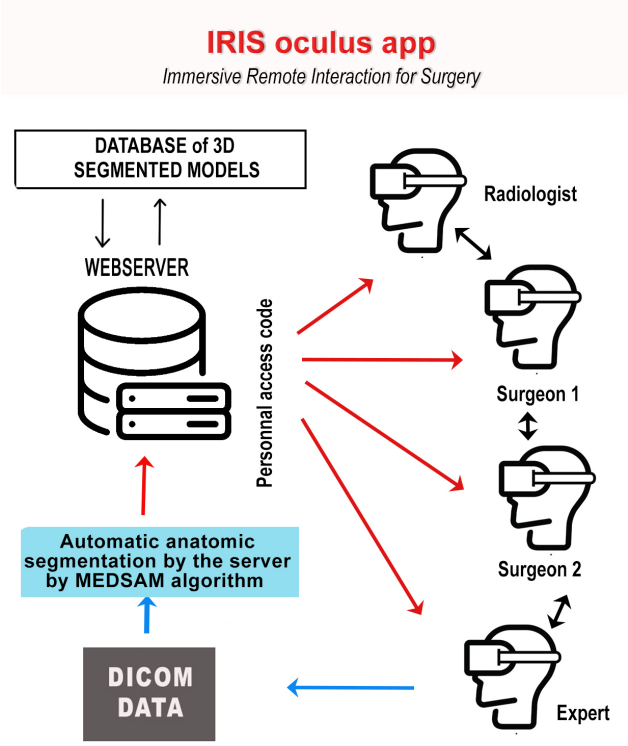


Fig 7 - Iris user diagram for collaborative remote discussion.

c. Iris Oculus workflow and user diagram

The segmented models on the server can be downloaded by users with a special security code via the IRIS-oculus app® . (Fig 7)

d. Anatomical segmentation

The server performs anatomical segmentation using Anything Model (SAM), which was developed by Meta® . The aim is to create a foundational model for image segmentation using multimodal examples. Meta has developed a promptable model and pre-trained it on a broad dataset using a task that enables powerful generalization. The goal is to use this model to solve a range of downstream segmentation problems on new data distributions using prompt engineering. The success of this plan hinges on three components: the task, the model, and the data. This represents a revolution in AI-based medical imaging and vision. Just as GPT-style language models are transforming natural language processing (NLP), vision language models (VLMs) and AI segmentation algorithms, such as SAM, are revolutionizing 3D anatomy modeling.

4. USE OF PATIENT'S AVATAR FOR SURGERY PLANNING AND SIMULATION

Once the segmentation has been processed automatically by the server or externally by 3D Slicer[12,15] (Fig 8), the 3D model becomes available to users via the Iris Oculus app. In some complex cases, experts must supplement the AI segmentation with manual segmentation performed using 3D Slicer to achieve more accurate and expert-level anatomical modeling. This enables remote, interactive, collaborative work in real time (see Fig 9) and allows up to four users to discuss the treatment strategy together.

Surgical planning steps

1. Meeting between the surgeon and radiologist (or the surgeon alone if VR settings are prepared) in front of the patient's avatar.
2. Immersive exploration: visualization of tumor-organ-vessel relationships, virtual dissection, and changing viewpoints to define approaches, margins, and areas to be preserved.
3. Formalization of the surgical plan: capture of key images or short VR videos integrated into the medical report or surgical file, with standardized textual descriptions.
4. Validation in a multidisciplinary team meeting: presentation of a few 3D/VR views during the meeting to align spatial understanding (particularly useful in oncology or traumatology and reconstruction with potential 3D printing).

5. Clinical applications of immersive VR across surgical specialties

For preoperative planning and intraoperative navigation, particularly in complex tumor resections, VR surgical planning leads to more precise and conservative surgeries.

1. **NEUROSURGERY**[16-20] Virtual reality (VR) and augmented reality (AR) are transforming neurosurgery by improving training, planning, craniotomy optimization, and intraoperative precision.
VR is used to plan AR-guided visualization for tumor resections, assess proximity to functional brain areas, and simulate craniotomies. (Example: Use of Surgical Theater and Elucis® in glioma and meningioma planning)
2. In **UROLOGIC SURGERY**[21,22] VR aids in planning nephron-sparing surgeries for renal tumors by simulating tumor-vascular relationships.
3. **ORTHOPEDIC SURGERY**[22-30] Surgeons use IVR to visualize and manipulate 3D models of fractures or complex anatomies, facilitating precise surgical planning[12] and understanding of difficult cases.
XR technology (extended reality, including VR & AR) improves the accuracy of implant, screw, or

prosthesis placement by guiding surgical procedures and reducing errors.

VR is widely used for training residents13 and surgeons, allowing them to simulate complex procedures such as arthroscopy, arthroplasty, fracture management, bone drilling, intramedullary nailing, and pedicle screw placement.

Bone sarcomas present unique surgical challenges due to complex 3D anatomy, the proximity of vital structures, tumor consistency, and the need to adjust the patient's position during resection procedures. The quality of resection is a key determinant of oncologic outcomes; therefore, VR-based preoperative planning is crucial for improving resection accuracy, ensuring adequate surgical margins, and reducing the risk of local or metastatic recurrence

4. **HEPATOBILIARY SURGERY**[31,32] Complex liver tumor resections benefit from VR models that display vascular and biliary anatomy. (Example: Planning of liver resections)

5. **CRANIO-MAXILLOFACIAL SURGERY**[33,34] Immersive virtual reality (IVR) and augmented reality (AR) are transforming maxillofacial surgery by improving training, planning, and surgical precision. The main applications include: maxillofacial reconstruction, orthognathic surgery

6. **ORAL SURGERY AND IMPLANTOLOGY**[35,36] VR provides an immersive three-dimensional environment that allows students and novice surgeons to practice implant placement without risk to patients. It facilitates repetition of movements, real-time error correction, and the acquisition of practical skills, going beyond traditional theoretical learning. VR can be combined with 3D-printed surgical guides, derived from virtual planning, to ensure accurate implant positioning. Creation of static guides or dynamic navigation systems for dental implantology, reducing positioning errors by 30-50%.

7. **LUNG SURGERY**[37-40] In lung surgery, immersive reality-including virtual reality (VR), augmented reality (AR), and mixed reality (MR)-is revolutionizing lung surgery on several levels, from preoperative planning to intraoperative navigation and surgical training.

They enable personalized preoperative planning of segmentectomies and other targeted procedures. Immersive virtual reality platforms, such as Surgical Reality (https://www.surgicalreality.com/platform) and PulmoVR, allow surgeons to visualize a patient's lung anatomy in 3D using their own scan images.

In pilot studies, the use of VR led to a change in surgical strategy in 40% of cases after an immersive review of the anatomy, highlighting the clinical impact of these tools.

They facilitate intraoperative navigation and guidance: AR acts as a 'surgical GPS'.

8. **ONCOLOGIC SURGERY**[41] Preoperative planning and intraoperative navigation- s in complex tumor resections: VR surgical planning leads to more precise and conservative surgeries. Multidisciplinary collaboration is often required.

VR demonstrates substantial potential benefits as a supportive care tool for cancer patients, effectively addressing their psychological, physiological, and psychosocial needs.

9. **RADIOTHERAPY**[42] is a little different: VR environments allow for interactive dose distribution and visualization of organs at risk, improving the delineation of organs at risk and target volumes, reducing planning time, and enhancing the accuracy and efficiency of radiotherapy. They offer promising applications, particularly for precise patient positioning and reducing anxiety.

10. **All these technologies** improve treatment accuracy by superimposing virtual 3D models onto real patients, while also facilitating training, planning, and robotic surgery[43].

These new tools represent a revolution in AI-based medical imaging and computer vision. Just as GPT-style language models are transforming natural language processing (NLP), vision language models (VLMs) and AI segmentation algorithms, such as SAM, are revolutionizing 3D anatomical modeling.

Multidisciplinary Collaboration Through Immersive VR

IRIS addresses the growing need for cross-specialty interaction in oncology. By sharing high-resolution 3D models over the internet, specialists, including radiologists, surgeons, and oncologists, can collaboratively evaluate patient-specific anatomies in real time, regardless of location. The immersive nature of IRIS fosters a deeper understanding of complex anatomy and stronger consensus in case management.

6. Strengths and Limitations of IRIS

The main strengths are: Full automation of segmentation and VR integration, remote and multi-user collaboration, simplicity, and interactivity make it a cost-effective and user-friendly system. No GPU is required for segmentation tools.

It is primarily suited for anatomy and surgery education and can be adapted to higher-resolution headsets (Apple Vision).

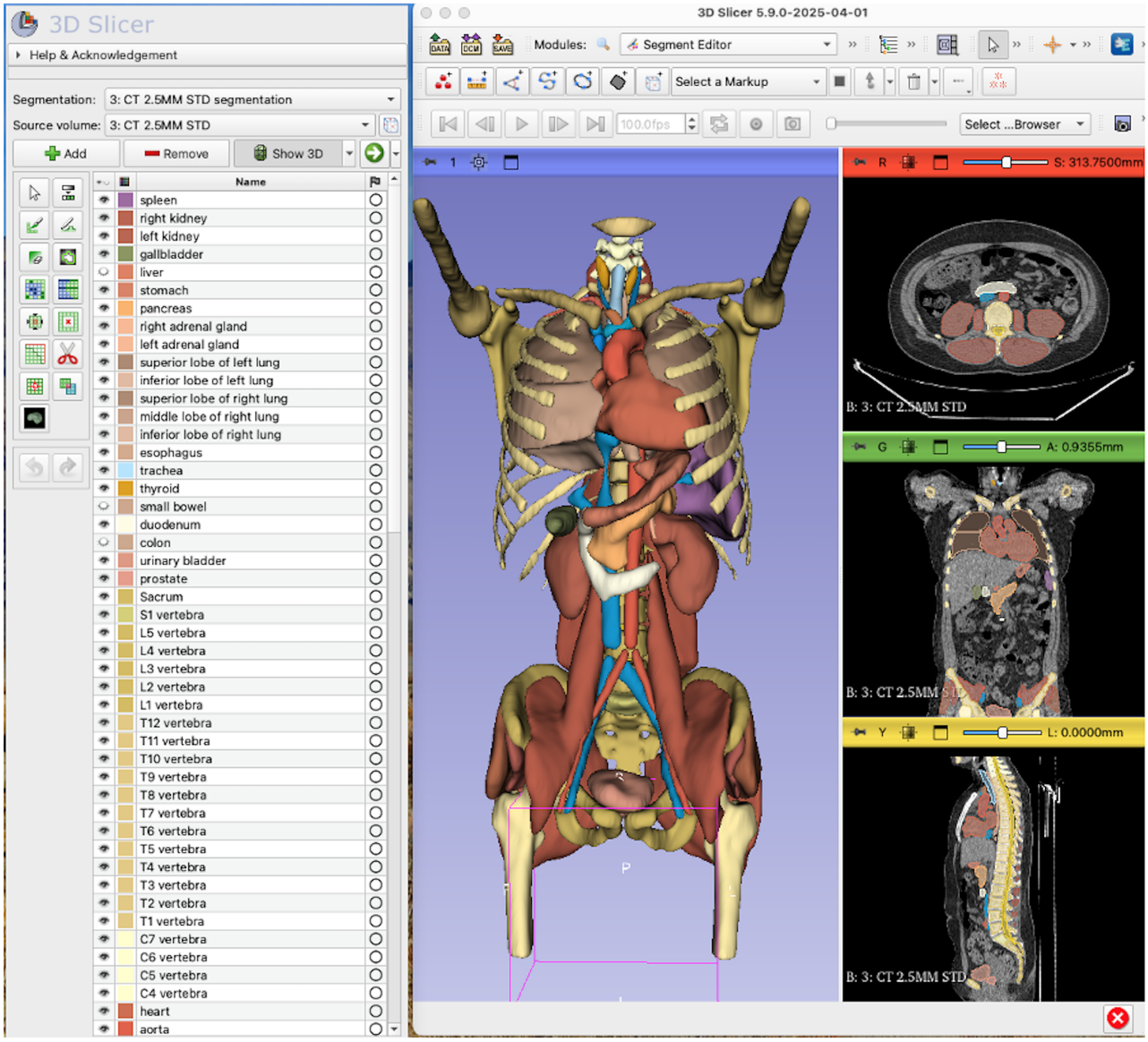


Fig 8 - Result of the 3D segmentation of a child using 3D Slice with the TotalSegmentator extension.

However, there are some important limitations to its use: The anatomical segmentation accuracy is insufficient for vessels in the context of surgical planning for liver and lung segmentectomies. The benchmark in this field is the Visible Patient® platform, which also has CE marking and is reimbursed by certain health insurance providers.

7. CONCLUSION

IRIS® represents a disruptive advance in the field of VR medicine, enabling true image-guided remote and interactive decision-making and strategy planning for surgeons.

This is particularly true for complex pathology cases and oncology, where a multidisciplinary approach is essential. By automating the segmentation process and enabling real-time remote collaboration, IRIS enhances clinical decision-making, fosters team coordination, and supports surgeon preparation and patient communication. It serves as a roadmap for personalized surgical planning.

This is made possible by a revolution in AI-based medical imaging and vision, thanks to new Vision Language Models (VLMs) such as SAM, which use AI algorithms to provide accurate automatic anatomical segmentation for 3D anatomical modeling.

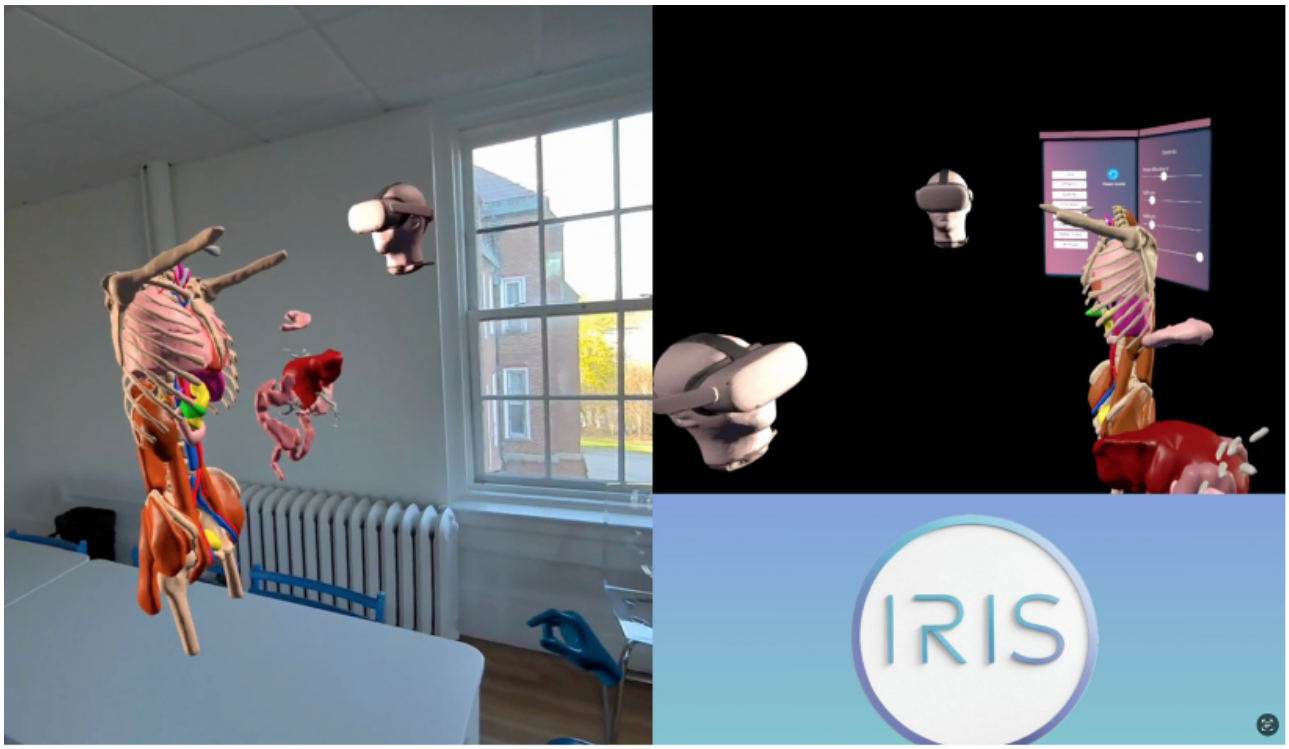


Fig 9 - Oculus display of the collaborative remote assessment with IRIS (3 users).

When used with the Oculus Meta 3S headset, the medical applications could include both educational anatomy and pathology as well as surgical planning discussions across a range of specialties.

Using immersive reality through the new IRIS® Oculus application, surgeons, radiologists, experts, and specialists can engage in remote interactive discussions: here, collaborative teamwork in immersive reality offers incredible opportunities and benefits. Medical cases can be reviewed and discussed by remote experts from around the world. Surgical approaches can be tested and explained by leading surgeons, and anatomy can be taught anywhere in a fully immersive 3D environment.

IRIS® changes the way medical teams collaborate, interact, discuss, and work. It enhances surgical and medical education and prepares young professionals for the surgery of the future.

Declaration of conflicts of interest

Doctor Jean-Francois UHL is the DG of the Diva3d company developping and selling the software (Iris medical viewer and Oculus apk).

All other authors declare that though they are involved in the development of the device, they have no conflict of interest, the paper underlining mainly it's diagnostic and scientific value.

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