ACS 2026 Surgeons and Engineers: A Dialogue on Surgical Simulation

P-A-02

Research In-Progress

A Mixed Reality and 3D Printing-Based Simulation System to Enhance Planning and Education in Hepatectomies

James Tan; Max Choe; James B. Piper, MD; Larry Walker; and Jihui Li, PhD

Appleby College, Oakville, ON, Canada; James Madison High School, Vienna, VA; Inova Fairfax Medical Campus, Falls Church, VA

Introduction: Hepatectomy is a critical but challenging treatment for liver tumors due to anatomical variability. Recent advances suggest that 3D-printed liver models and mixed reality (MR) tools can enhance surgical planning, visualization, and education. In this study, we developed a simulation system integrating MR and 3D printing to support hepatectomy training and planning.

Methods: A cadaveric torso with a simulated liver tumor underwent contrast-enhanced CT imaging. Hepatic structures were segmented and reconstructed using Mimics software. The liver model was imported into a custom Unity-based MR application used with a HoloLens 2 headset, allowing three residents to interactively explore anatomy, plan resections, and perform virtual hepatectomies (Figure 1A). Resected portions from the MR planning — including blood and bile vessels, parenchyma, tumor, etc. — were individually exported as STL files for multi-color 3D printing (Figure 1B). A hepatectomy was then performed on the cadaveric torso, using the printed model as a visual and tactile reference. Workflow, usability, and accuracy were assessed by an experienced hepatobiliary surgeon.

Preliminary Results: Trainees reported that the immersive MR environment improved spatial understanding of hepatic anatomy, particularly vascular relationships and tumor location. It also facilitated safe and repeatable rehearsal of resection strategies. Meanwhile, the 3D-printed liver segment model, based on MR planning, provided valuable tactile and visual feedback as well as direct resection guidelines during cadaveric surgery. The supervising surgeon noted improved efficiency, margin clarity, and confidence in both planning and execution.

Next Steps: We will further assess the system's handling of anatomical variability and reproducibility using additional cadavers. Future MR interface iterations will focus on intuitive controls and customization. Evaluations from residents and surgeons will continue to focus on usability, accuracy, and educational value. Long-term, clinical trials will explore patient-specific applications in operative planning and surgical training.

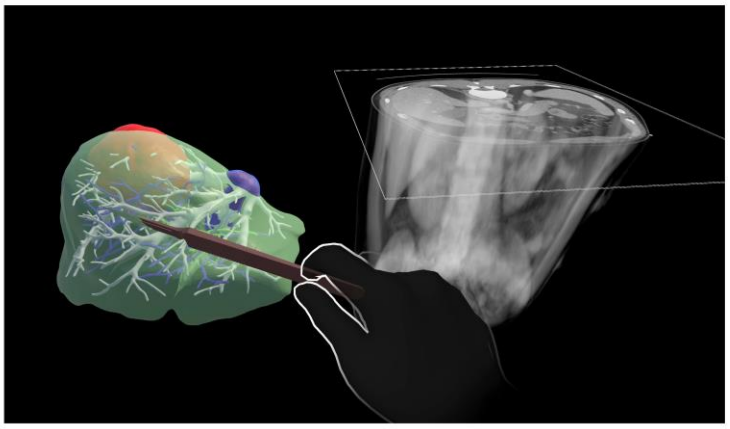

Figure 1A

Figure 1B