

Mixed Reality in Cardiac Surgery: Towards a Training Simulator for Mitral Valve Repair Intervention

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INTRODUCTION

Mitral regurgitation is a condition characterized by the abnormal backflow of blood from the left ventricle to the left atrium. The MitraClip system (AbbottTM) is a device designed for percutaneous intervention, deploying a clip to prevent this backflow. Despite its effectiveness, the procedure is technically demanding, requires fluoroscopy guidance (hence exposure to X-ray radiation), and relies heavily on the surgeon's dexterity [1]. This study investigates if Mixed Reality (MR) can enhance surgical training with the MitraClip device [2].

MATERIALS AND METHODS

The physical system included a cardiovascular anatomical phantom, the MitraClip system, and an electromagnetic (EM) sensor. The simulation environment (SE), built in Unity3D, accurately replicated this setup.

Two visualization interfaces were developed for the SE. (1) The 2D Interface replicates traditional methods using fluoroscopy and transesophageal echocardiography (TEE). Fluoroscopy provides a top planar view, while TEE offers views of the Left Ventricular Outflow Tract (LVOT) and commissures to visualize the mitral valve. (2) The MR Interface offers a 3D immersive view of the setup using a head-mounted display, enhancing spatial perception and intuitive interaction. The interfaces were coupled with the physical system via the EM sensor.

To evaluate the advantages of using MR technology, a user study was conducted. The 24 participants were randomly assigned to use one of the two interfaces to navigate a digital twin of the catheter through a simulated static heart environment. The task involved navigating the catheter to a specific anatomical landmark. Evaluated metrics included task completion time (T), number of collisions with heart walls (NC), catheter's tip final position error (PE), and user feedback.

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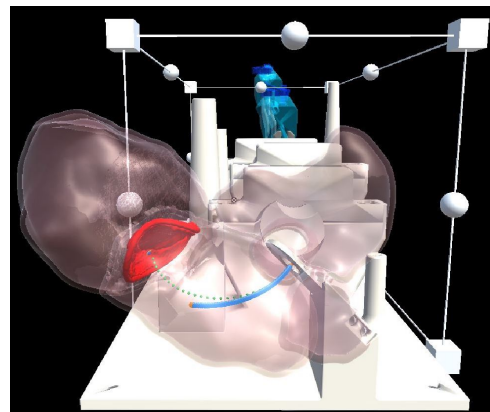


Fig. 1 MR Interface. In blue, the catheter digital twin.

RESULTS

The study revealed that the MR Interface provided better results across all metrics compared to the 2D Interface. The statistical analyses showed that the median T of the MR Interface is 55% lower than the median T of the 2D Interface. A lower median T and lower NC when using MR, indicate faster learning and improved safety. The Mann-Whitney U test confirmed significant differences in PE, with MR users reaching target positions more accurately and consistently. Users subjective evaluations also favored MR, reporting lower effort, frustration, and demand.

DISCUSSION

The study supports the potential of MR in enhancing surgical training. Future improvements should enhance the echography simulation and incorporate realistic deformable dynamic models of the heart to increase training realism.

REFERENCES

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