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Case Report

Case report: Use of markerless augmented reality system for ventriculoperitoneal shunt placement

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ABSTRACT

Background: Ventriculoperitoneal (VP) shunt placement is one of the most commonly performed neurosurgical procedures, yet failure rates remain very high. Surface landmarks are typically used to guide VP shunt placement, but they are not reliable in identifying the target anatomy. Augmented reality (AR) is a promising new technology that has the potential to improve the accuracy and effectiveness of neurosurgical procedures. We describe the use of AR for the surgical planning of a VP shunt.

Case Description: A 62-year-old male with a history of subarachnoid hemorrhage presented with delayed hydrocephalus. A computed tomography scan was obtained that confirmed dilated ventricles, requiring a right VP shunt. The patient was brought to the operating room, where the AR system was used for visualization and planning.

Conclusion: In this study, we describe the use of AR for VP shunt placement. The AR system consists of a Microsoft HoloLens 2 head-mounted display and a novel markerless registration system, which was used to register patient-specific 3D models onto the patient's head for visualizing target anatomy and planning an operative approach. The AR system was used to plan the VP shunt placement in the operating room. This system is easy to use and provides a visualization of the patient's anatomy, which can be used to plan an optimal trajectory. We believe that this has the potential to improve the accuracy and outcomes of VP shunt placements, and further studies are needed to characterize the system's accuracy and benefits.

Keywords: Augmented reality, Mixed reality, Presurgical planning, Ventriculoperitoneal shunt

INTRODUCTION

Insertion of a ventriculoperitoneal (VP) shunt is one of the most frequently performed neurosurgical procedures for the management of hydrocephalus. Although it is a frequently performed procedure, the failure rate of shunts is up to 39% in 1 year. The most common cause of failure is obstruction of the catheter.[4,7] Other causes of shunt failure include infection, overdrainage, and mechanical failure.[6] Given such high failure rates, optimizing the procedure with correct placement is critical. VP shunts are commonly placed with a freehand approach based on anatomic landmarks, yet freehand technique using surface landmarks has been shown to be a risk factor for inaccurate catheter placement.[7] In addition, it is not uncommon for surgeons to estimate insertion points and trajectories based on measurements performed on preoperative imaging. This is especially the case when targeting traditional insertion points such as Kocher's, Frazier's, and Dandy's points, which are estimated by distance measurements along the skull.[8] Using surface landmarks or measurements from preoperative imaging to guide catheter placement is subject to imprecision. It can be especially unreliable when there is abnormal anatomy, such as in the setting of brain swelling, infarction, and surgical changes.[4] In the case of complex ventricular anatomy such as shifted or slit ventricles, neuronavigation has been shown to improve accuracy significantly. These systems allow for more precise access to ventricular targets using either optical or electromagnetic tracking or registration methods. Electromagnetic systems are particularly effective as they provide image guidance without the need for head fixation.[2,3] Despite the advantages of currently available image guidance systems, their size, cost, and setup requirements can be prohibitive.

Augmented reality (AR) allows for 2D patient imaging, such as magnetic resonance imaging and computed tomography (CT), to be appreciated in 3D space. AR is a technology that can superimpose 3D virtual models onto the user's real-world environment. This technology has the potential to improve the accuracy and effectiveness of surgical planning by providing surgeons with a 3D view of target anatomy and its surrounding structures that can be used to plan the ideal procedural approach. AR provides the benefits of both 3D visualization and the ability to visualize these models superimposed onto the real environment and patient. The purpose of this study is to assess the benefit of a novel AR registration system for operative planning of VP shunt placement.

CASE DESCRIPTION

A 62-year-old male with a history of subarachnoid hemorrhage presented with delayed hydrocephalus, requiring a right VP shunt. CT scan confirmed dilated ventricles [Figure 1].

Segmenting anatomical structures

3D models were generated based on the patient's preoperative CT scan that was obtained the morning of the procedure. Anatomy of interest – skull, and ventricles – were manually segmented using ITKsnap. The patient's face was segmented and reconstructed for registration through auto-segmentation algorithms (Hoth Intelligence Inc., Philadelphia, Pennsylvania). All segmented structures were merged and converted into a 3D digital model [Figure 2]. The digital models underwent basic processing to reduce the file size to optimize performance, visual quality, and usability for an AR head-mounted display (HMD).

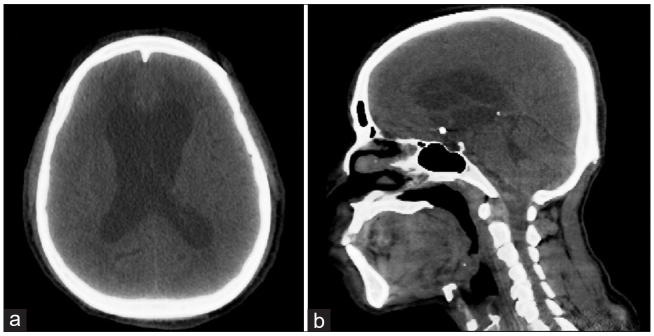

Figure 1: Diagnostic computed tomography (CT) study demonstrating the vestibular schwannoma (a) axial CT and (b) sagittal CT.

AR technology platform

The AR application was developed by Hoth Intelligence (Philadelphia, Pennsylvania) to operate on the Microsoft HoloLens 2 HMD (Redmond, Washington). The Microsoft HoloLens 2 is an untethered optical see-through HMD that superimposes virtual content (i.e., holograms, images, and screens) onto the users' real-world field of view. A clinical workflow of the AR system is described in [Figure 2].

3D model registration to patient

The application used in this study superimposes 3D digital models onto the head using a proprietary ultra-fast, markerless registration process. To register the anatomy with the subject, the user looks at the subject's head while wearing the HMD. Information from the headset sensors (depth sensor, RBG camera, and stereo sensor) are merged with coordinate data from the preoperative CT scan to align the 3D model to the patient's head. After the patient was placed in the operative position, the patient-specific 3D model was registered onto the head through the AR headset [Figure 3].

Mixed reality viewing

Once registered, the physician was able to freely move around the patient to visualize the 3D model overlaid onto the patient's head from different perspectives [Video 1]. The added AR visualization allowed the physician to visualize the location of the ventricles and the skull to assess possible approaches and burr-hole locations. The physician was able to use a holographic trajectory tool to visualize various insertion locations and trajectory approaches for the shunt placement [Figure 3]. For this case, the AR headset was used for planning trajectory and approach before catheter insertion and was not worn during the insertion.

Surgical strategy

Areas of the head, neck, and abdomen were prepped for incision. Dissection was carried down to the periosteum,

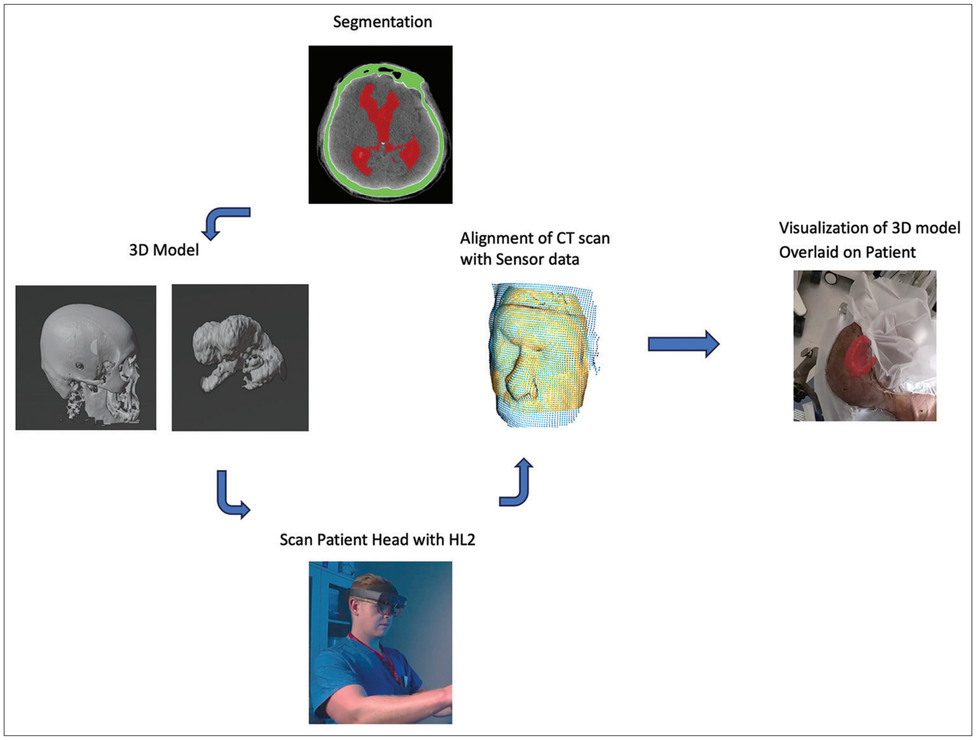

Figure 2: Workflow of the augmented reality (AR) technology platform. The patient's anatomy is first segmented and converted into a 3D model. The model is loaded onto the Microsoft Hololens 2 (HL2) AR headset. While wearing the headset, the surgeon scans the patient's head. Registration algorithms are processed on the headset, and the 3D model can be visualized aligned/overlaid with the patient's head.

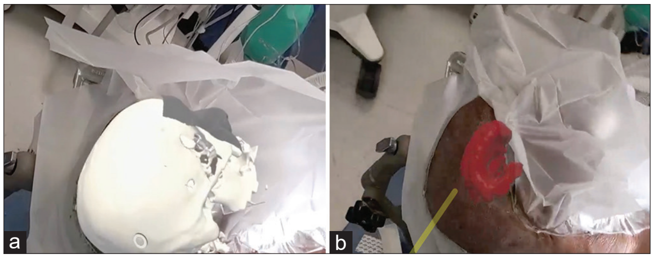

Figure 3: Surgeon's view through the augmented reality headset displaying (a) 3D reconstruction of patient's skull overlaid on patient's head and (b) 3D reconstruction of patient's ventricle along with insertion trajectory overlaid on patient's head.

and a burr hole was placed. Once the dura was coagulated and incised, neuronavigation was used once again to guide a catheter into the ventricle. The proximal catheter was connected to the valve and secured on the bone. The distal catheter was tunneled toward the right upper quadrant of the abdomen, connected to the reservoir, and tested. A right lower quadrant skin incision was made to introduce a trocar into the peritoneal cavity. Shunt tubing was then tunneled with the tip laying in the right lower quadrant. The galea and all skin incisions were then closed.

Video 1: Video capturing the surgeons' view through the headset of the 3D model overlaid onto the patient's head.

DISCUSSION

We describe a novel use of AR for use in presurgical planning for VP shunt placement. AR allows for integrating patient-specific anatomic information in 3D into the surgeon's real-world environment without requiring the surgeon to look away from the patient and surgical field. We describe our experience using AR to overlay patient-specific 3D models onto the patient's head with a markerless registration system. AR has emerged as a promising technology, gaining considerable traction in the field of neurosurgery with a range of applications in neuroanatomy education, surgical training, and intraoperative guidance.[1,5]

Image-guided surgery gives the surgeon the ability to visualize patient-specific anatomy to plan an appropriate approach and trajectory. Studies have shown improvements in catheter accuracy with image guidance.[1,4] Despite this, image guidance is not regularly employed in VP shunt procedures. This is in part due to the lack of evidence of the long-term benefits of image-guided shunt placement, as well as the high cost and poor usability of currently available systems. In order for such a system to be widely adopted in clinical practice, it must be fast, easy to use, and low-cost. Although this study did not utilize the AR technology intraoperatively, it demonstrates that the AR system and marker-less registration system can be used to overlay the visual information effectively and efficiently onto the patient in the operating room and operative position. This system has several advantages for use in preoperative planning. Patient CT imaging was obtained on the morning of the procedure, and the model was generated within a few hours. The system only requires a small headset that is worn by the user with no additional hardware brought into the operating room. In addition, the registration of the 3D model to the patient takes around 10–20 s, which does not add significant time to the operative setup time.

The AR system allowed the surgeon to visualize the patient's abnormal target anatomy and to plan an appropriate catheter trajectory accordingly. The surgeons were able to visualize the 3D reconstructions of the patient's anatomy. They were also able to plan and visualize virtual trajectories in real-time, although not at the time of burr-hole drilling and catheter insertion. This technology was used successfully in the operating room setting preoperatively, but this study has several limitations. This is a case study, and future work should include a larger number of cases to demonstrate improvements in placement accuracy as well as patient outcomes when using this AR visualization system. Future studies should include validation of the system's registration accuracy and speed. The utility of the system across a variety of pathologies and user level of training should also be evaluated. The current system does not include instrument tracking in real-time. The ability to align surgical tools precisely with the trajectory and to determine when a surgical tool has reached a target structure could further improve the accuracy of catheter placement.

CONCLUSION

In this study, we report the use of AR visualization for planning VP shunt placement. This technology is advantageous in surgical planning as it allows for enhanced visualization with a fast, user-friendly setup. Future studies are needed to characterize the accuracy of this novel technology further, its impacts on surgical outcomes, and cost and usability in various clinical scenarios.

Ethical approval

Institutional Review Board approval is taken, approval number HP-00104849 Date: 10/22 University of Maryland Medical Center.

Declaration of patient consent

Patient's consent not required as patient's identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Durrani S, Onyedimma C, Jarrah R, Bhatti A, Nathani KR, Bhandarkar AR, *et al*. The virtual vision of neurosurgery: How augmented reality and virtual reality are transforming the neurosurgical operating room. World Neurosurg 2022;168:190-201.
2. Gilard V, Magne N, Gerardin E, Curey S, Pelletier V, Hannequin P, *et al*. Comparison of electromagnetic neuronavigation system and freehand method for ventricular catheter placement in internal shunt. Clin Neurol Neurosurg 2017;158:93-7.
3. Jung N, Kim D. Effect of electromagnetic navigated ventriculoperitoneal shunt placement on failure rates. J Korean Neurosurg Soc 2013;53:150-4.
4. Lind CR, Tsai AM, Law AJ, Lau H, Muthiah K. Ventricular catheter trajectories from traditional shunt approaches: A morphometric study in adults with hydrocephalus. J Neurosurg 2008;108:930-3.
5. Olexa J, Cohen J, Alexander T, Brown C, Schwartzbauer G, Woodworth GF. Expanding educational frontiers in neurosurgery: Current and future uses of augmented reality. Neurosurgery 2023;92:241-50.
6. Reddy GK, Bollam P, Shi R, Guthikonda B, Nanda A. Management of adult hydrocephalus with ventriculoperitoneal shunts: Long-term single-institution experience. Neurosurgery 2011;69:774-80.
7. Wilson TJ, Stetler WR Jr., Al-Holou WN, Sullivan SE. Comparison of the accuracy of ventricular catheter placement using freehand placement, ultrasonic guidance, and stereotactic neuronavigation. J Neurosurg 2013;119:66-70.

8. Yamada S, Ishikawa M, Nakajima M, Nozaki K. Reconsidering ventriculoperitoneal shunt surgery and postoperative shunt valve pressure adjustment: Our approaches learned from past challenges and failures. 2021;12:798488.

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