CIS 2 Critical Review

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Background

An External Ventricular Drain (EVD) insertion, or Ventriculostomy, is a bedside procedure conducted by neurosurgeons to drain cerebrospinal fluid (CSF) to relieve pressure in the brain. The target of this procedure is the Foramen of Monro. The steps for the procedure are taking a CT scan pre-procedure, drilling a burr hold, and inserting a catheter. This is a time sensitive procedure with neurosurgeons relying on prior experience and their ability to reason out CT scans. However, about a third of insertion attempts are misses that could be partially due to differences in anatomy among patients. These misses are costly, not only as far as their impact on procedure time, but also due to damage to the surrounding tissue. Thus, for all of the reasons listed above, there is a need for a low cost, accurate guidance system that would aid in EVD.

Paper Purpose

This paper proposes a head-mounted mixed reality guidance system to aid neurosurgeons in conducting EVD procedures. The aim of this paper is to assess the feasibility and accuracy of the proposed system/workflow through a preliminary study. Based on the study, the authors concluded that their solution is a viable option when it comes to aiding neurosurgeons with executing an EVD.

System Summary

The proposed system provides an overlay of the internal anatomy of the patient based on CT scan and does path-planning calculations to project guides for the procedure. The workflow of the system on a high-level is the following: attaching gel electrodes, preoperative CT scans, preoperative processing, manual registration between the Hololens and the patient, drilling burr hole based on guide, inserting catheter based on projected guide, and postoperative CT scan. The preoperative processing step can be broken down into segmenting the ventricles, markers, and target of the CT scan, target localization, trajectory calculations, manually checking each slice of CT to make sure the trajectory is not going through important structures, and visualizing that information. The manual registration step is done through voice commands and gestures and is checked by determining if the markers in the virtual and actual environments line up as well as ears and nose. The neurosurgeon is then ready to start the procedure. The HMD then provides guides for the drilling and insertion step. It is important to note that the surgeon hits the target when CSF fluid comes out of the catheter, which translates to about within

3mm of the target. If at any point if the projection is no longer aligned with the patient, then the surgeon would reregister the system.

Study Summary

The study consisted of one neurosurgeon performing 30 EVD procedures: 15 with the mixed-reality system and 15 without. For each case, the system was assessed for “technical feasibility” and “technical accuracy”. The measurements for technical feasibility were the amount of additional time it took to use the mixed-reality system versus the baseline method, number of projection shifts, number of re-registrations done, and post-operative complications. The measurements for technical accuracy were accuracy of insertion and number of passes required to hit the target. Accuracy of insertion was determined by calculating the distance between the target and the tip of the catheter using a postoperative CT.

Result Summary

The results from this study show that the proposed mixed-reality system could be a viable option in aiding neurosurgeons with the EVD procedure. Note: the figures below were generated from the data provided in the paper and not from the paper.

Distance between Catheter Tip and Target

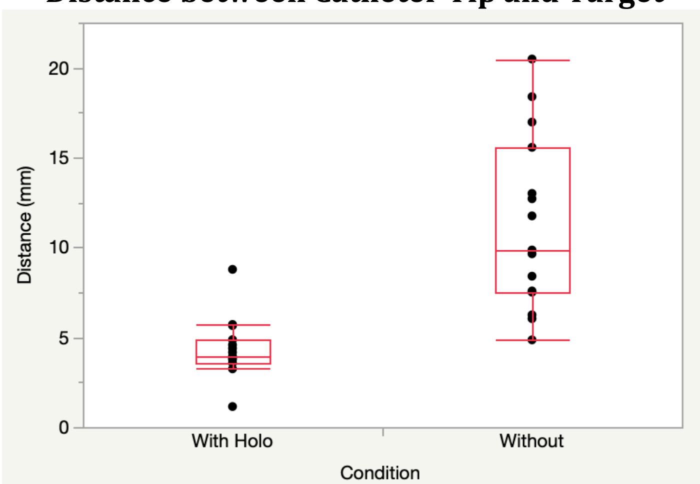

Figure 1. Graph shows distribution for all insertions in the study separated by condition.

The accuracy (see Figure 1) achieved by the mixed-reality system (M=4.34) was significantly better than the control group (M=11.26). In addition, there was significant decrease in the number of required attempts for the proposed system (M=1.07) than the control (M=2.33).

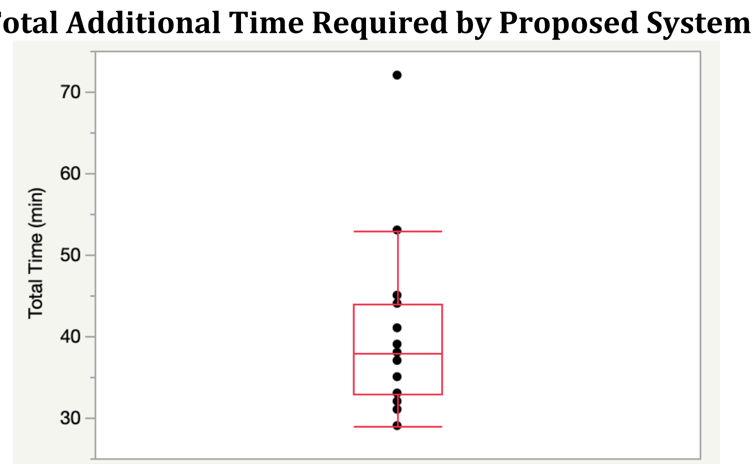

Figure 2. Graph shows the distribution of the total additional time the mixed-reality system takes.

On average, the mixed- reality system requires 40.20 more minutes than the baseline (see Figure 2). In addition, there were no procedure related complications, and the average number of re-registrations is 0.43.

Assessment

Strengths. One definite strength of the paper is that they were able to conduct a study with real-world applications, not just on a simulation or a phantom. Another strength is that the study involved the entire workflow and not just the insertion of the catheter part of the procedure.

Weaknesses. The journal paper does not provide enough information to reproduce this study and system implementation. The paper oddly provides a detailed description for the obtained CT scans but lacks detailed information about the rest of the implementation such as the registration process. In addition to the fact that the results are irreproducible, the time measures collected for the amount of time it takes to do certain steps of the workflow are not necessarily meaningful as it is not clear what each step exactly entails. This would make it difficult for anyone other than the authors to improve the system to decrease processing times.

Another weakness of this paper is the fact that the study did not use more than one neurosurgeon. The EVD procedure, as mentioned above, is generally conducted by neurosurgery residents with a range of expertise and success is dependent on that experience. So, having the study based solely on one neurosurgeon's experience would not be a representative study. Not to mention that there was no information provided about this neurosurgeon as far as experience with both the procedures and HMDs. It was also a missed opportunity to explore how performance improves as the neurosurgeon performed more procedures with the mixed-reality system.

The way the paper displayed the results was another weakness. The numerical results were displayed in tables and were not visually informative. Instead, the data should have been presented like Figure 1, which would provide information like the distribution of the data. Another weakness is that the title seems to be misleading.

Possible Future Work. A few clear possible extensions of this work are conducting another study with more neurosurgeons of varying experience associated with EVD and finding ways to shorten the time of pre-procedure processing. Because of the lack of detail associated with the mixed reality system, the second work listed cannot be more specific.

Relevance

The reason I chose this paper in the hope to learn about other techniques and systems using mixed-reality that were created for aiding in Ventriculostomy (EVD) procedures. In addition, I was initially intrigued by the user study since it involved a neurosurgeon and was applied in the real world. There is an obvious relevance between this paper and my project as both address the need for some mixed-reality HMD system to aid in EVD procedures. Also, the paper provides an example of a way to evaluate a system similar to my project.

Conclusion

This paper overall proposed and proven a feasible mixed-reality HMD navigational guide that could aid neurosurgeons with the EVD procedure. However, it is important note the major limitations associated with the results from the preliminary study as described in the weakness section.

Bibliography

Li, Ye., Chen, X., Wang, N., Zhang, W., Li, D., Zhang, L., Qu, X., Cheng, W., Xu, Y., Chen, W., & Yang, Q. (2018). A wearable mixed-reality holographic computer for guiding external ventricular drain insertion at the bedside, *Journal of Neurosurgery JNS*, *131*(5), 1599-1606.