VENTRICULOSTOMY PRACTICE ON A LIBRARY OF VIRTUAL BRAINS USING A VR/HAPTIC SIMULATOR IMPROVES SIMULATOR AND SURGICAL OUTCOMES

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Research Question: Would practice on a simulator library of virtual brains result in improved performance 1) on a novel virtual brain, and 2) in actual surgical procedures?

Background:

Ventriculostomy, insertion of a catheter into a fluid-filled ventricle deep in the brain, is a closed-head procedure often performed by beginning neurosurgery residents. Several passes through the brain may be required for a successful cannulation. Feedback on the final location of the catheter tip is unavailable until the post-procedure CT scan, making it difficult for residents to relate their technique to the final outcome and improve their aim. Simulator practice may accelerate learning and shorten the learning curve, and thereby decrease complications due to inexpert technique.

We developed a library of 15 virtual brains for the ImmersiveTouch® workstation, a head- and hand-tracked augmented virtual reality and haptics simulator (1), based on actual CT scans and representing a range of normal and abnormal anatomies including normal, shifted and slit ventricles. The library allows neurosurgery residents to practice with multiple anatologies and obtain immediate 3-D feedback of the location of the catheter in the brain.

Validity data based on resident surveys regarding realism and utility was reported previously (2); this study reports on the effect of simulator practice on virtual and live performance.

Methods:

Simulator Practice: Neurosurgery residents participated in two hours of individual simulator practice on the library of virtual brains, including visualizing the 3-D location of the catheter within the brain immediately after each attempt. Three brains, one of each ventricle type, were presented as a pre-test; residents had three attempts per brain. These three plus nine other virtual brains were then presented for free practice in which the resident would aim at the ventricle through a burrhole, decide where they were in the ventricle based on haptic feedback (a change in tactile sensation when passing from brain tissue into the ventricle), and then “open” the brain to visualize in 3-D the location of the catheter in the ventricle. The two hour individual practice session was followed by a three-brain post-test using novel brains. The post-test was repeated about 1 month after the initial practice session.

Live surgery outcomes were assessed for 3-6 months before and 1 month after simulator practice, including whether cannulation was successful, whether cannulation succeeded on the first attempt or not, entry into the lateral (vs. third or fourth) ventricle space (catheter location in the lateral ventricle decreases complications requiring a repeated procedure), and hemorrhage.

Data Analysis: A series of generalized linear mixed models (GLMM) were fitted to the data using SAS 9.2 PROC GLIMMIX, with full maximum likelihood estimation (METHOD=QUAD) and either logistic or normal distributions, depending on the nature of the outcome. In each model, random intercepts were fitted for residents using an unstructured covariance matrix, to account for clustering of responses within resident.

Results:

Simulator Practice: Sixteen residents generated a total of 397 simulated ventriculostomy attempts, with three attempts per resident per brain type per time. Relative to pre-intervention performance, residents were more successful in cannulating a novel virtual brain immediately post-intervention (OR=3.43, 95% CI=[1.74, 6.77], p<0.001) as well as at follow-up (OR=2.59, 95% CI=[1.24, 5.41], p=0.01), but performance at follow-up was significantly worse than immediately post-intervention (p<0.001).

Live surgery outcomes: Twenty-three residents provided live surgical data, generating a total of 176 ventriculostomy data points (not all participated in simulator training). Cannulation was successful in all but 3 of these surgeries, and thus success of cannulation could not be modeled. Cannulation succeeded on the first attempt in 152 surgeries (86%).

Likelihood of succeeding on first attempt was 72% pre-training vs. 91% post-training (OR=3.76, 95% CI=[0.86, 16.4], p=0.08). Thus, the effect of training on likelihood of succeeding was in a positive direction, but did not reach statistical significance. After training the catheter was significantly more likely to have appropriately entered the lateral ventricle as opposed to other spaces (OR=2.51, 95% CI=[1.19, 5.28], p=0.02). Hemorrhages occurred in 16 surgeries (9%), and were not predicted by training or ventricle type.

Discussion

Unlike traditional simulations, the library of virtual brains allowed residents to practice the procedure on a variety of normal and abnormal anatomies and a range of difficulty levels. This approach follows Issenberg et al’s recommended best practices for simulation (2), facilitating transfer of skills to novel simulated and live procedures.

Conclusions

Practice on a VR/haptic simulator with a library of virtual brains produced improved performance in neurosurgery residents, as measured by simulator outcomes and catheter location in live surgery. Simulator practice, especially by novice residents, may accelerate learning and shorten the learning curve for this common procedure, and thereby decrease morbidity and complications due to inexpert technique.

References

Knebel SB et al: Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. Medical Teacher, 2005; 27(13-19-28)

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This work was supported in part by ARHQ Grant # 1R03HS017361-0 to Dr. Yudkowsky