Novel Surgical Augmented Reality System

James Williams[1], Daniel Lammers[1], Andrew Francis[1], Beau Prey[1], Luke Pumiglia[1], Maziyar Askari[2], Xingxing Liu[2], Matthew Eckert[1], Jason Bingham[1], John McClellan[1], Yang Liu[2]

[1]Madigan Army Medical Center
[2]University of Iowa

Aims: The goal of this project is to develop and test a novel surgical augmented reality system. The system is capable of providing surgical guidance in darkout or low-light conditions, and providing picture-in-picture (PIP) ultrasound imaigng [1]. Dynamic 3D surgical magfication were provided in real-time with AR content such as ultrasound. General surgeons performed focused assessment with sonography for trauma (FAST) exams using an intra-abdominal hemorrhage model.

Materials and Methods: We have developed a prototype surgical augmented reality system with 2 to 5 times dynamic magnification and autofocus capabilities. The system is able to be paired with other medical equipment such as ultrasound devices and vital sign monitoring via wireless technology and directly display imaging results within the user's field of view via PIP imaging. The imaging module consists of 2 separate and identical imaging detectors for stereoscopic imaging. The distance between the microdisplays (inter-pupillary distance) can be adjusted to personalized settings. Illumination is based on high-power LEDs controlled by a hand controller that can fine tune the NIR light intensity. Autofocus is implemented using liquid lenses without using any moving parts. To reduce weight, most mechanical parts in the system are designed with plastic materials. A post mortem fetal pig model of intra-abdominal hemorrhage was used to evaluate the ability of surgeons to perform a FAST exam . A total of 8 animals were used for purposes of the study. The peritoneal cavity of half of the animals was injected with 200 mL of normal saline via a 14-gauge needle to mimic intra-abdominal hemorrhage. The peritoneal cavity of the other half of the animals was entered using a 14-gauge needle, however no fluid was injected. All 8 animals were then arranged in a random order on the examination table. Surgeons, who were blinded to the animal arrangement, were then asked to perform a FAST exam on each animal.

Results: Figure 1 depicts the prototype system being worn while in the back of a helicopter in low light conditions. Five surgeons completed a total of 40 FAST exams. Of the 40 exams performed, 95% (N = 38) resulted in correct identification of intra-abdominal fluid or lack thereof. Both incorrect exams were false positives, resulting in 100% sensitivity, 90% specificity, 90.9% positive predictive value, and a 100% negative predictive value. Representative screenshots from the PIP display depicting positive and negative FAST examinations under blackout conditions are shown in Figure 2.

Fig 1 Prototype system in use in the back of a helicopter.

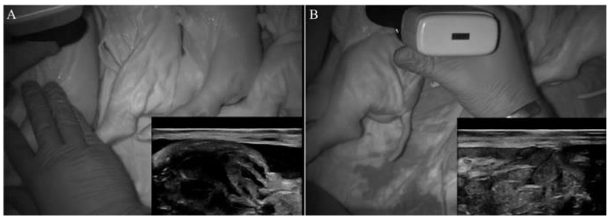

Fig. 2 (A) Post mortem fetal pig FAST examination with intra-abdominal fluid as viewed through the prototype system. (B) Post mortem fetal pig FAST examination without intra-abdominal fluid.

Conclusions: There is currently a gap for surgical visualization devices with dynamic 3D magnification and AR capabilities. The novel ultrasound compatible surgical visualization system used in this study was successful in identifying intra-abdominal hemorrhage in an easily reproducible animal model under blackout conditions. This study demonstrated the feasibility of surgical visualization with 3D magnification and AR in real time.

Acknowledgements: We thank the Madigan Army Medical Center Department of Clinical Investigations staff for their contributions to this work.

References:

[1] Williams, James et al. "Who Says You can't go FAST at Night? Use of a Novel Ultrasound-Capable Night Vision Device for Prehospital Medical Personnel to Identify Noncompressible Truncal Hemorrhage." Surgical innovation vol. 31,6 (2024): 577-582.