A Microcontroller-based Simulation Platform for Neurosurgery Training

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Introduction

Surgical simulation has the potential to supplement and enhance traditional resident training. However, the high cost of equipment and limited number of validated scenarios have hindered wider integration of simulation in neurosurgical education. Here, we demonstrate a novel, low-cost simulation platform that recreates the stress of intra-operative complications using a combination of hands-on and computer elements.

Figure 1

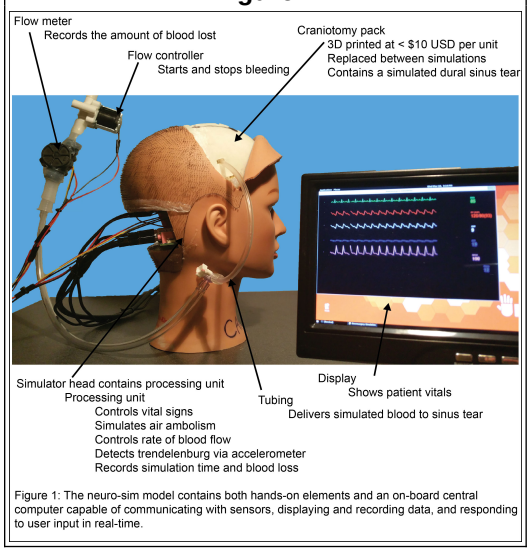


Figure 1: The neuro-sim model contains both hands-on elements and an on-board central computer capable of communicating with sensors, displaying and recording data, and responding to user input in real-time.

Methods

This study was approved by the Institutional Review Board at OHSU, and informed consent was obtained.

Neuro-Sim Model

The Neuro-Sim model is a single reusable unit that contains an UDUU microcomputer running UBUNTU with a custom script written in PYTHON to simulate patient vital signs, record simulation data and interact with an on-board ARDUINO shield. The ARDUINO controls an accelerometer to detect patient head angle, a flow controller to start and stop bleeding, and a flow meter to record blood lost during the simulation. The Neuro-sim model also holds the "craniotomy-pack" which is a single use 3D-printed skull with realistic dura, tubing to deliver simulated blood, and a 3-D printed brain model.

Trainee Monitoring

During the simulation each study participant wore a wrist-watch heart monitor MIO-Alpha to record heartrate (HR) during the simulation. Study participants were asked to fill out a questionaire at the end of the simulation

Didactics

A faculty neurosurgeon was present during the simulation to offer context specific didacts regarding craniotmies, sagittal sinus bleeding, air embolism, and dural manipulation.

Statistical Analysis

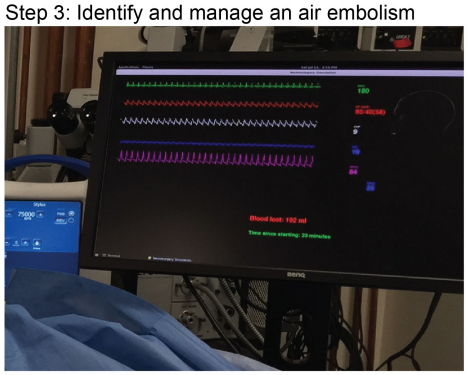
All data displayed as mean +/- SD unless otherwise indicated. Relative tachycardia was calculated as HR 2 SD above the mean HR. Pairwise comparisons were made using Paired Students t-test

Figure 2

Step 1: Perform craniotomy

Step 2: Manage a sagittal sinus tear

Step 3: Identify and manage an air embolism



Results

Trainee HR was elevated compared to published norms for resting HR. The bleeding and air embolism complications caused increased HR during the events (Figure 3).

Figure 3

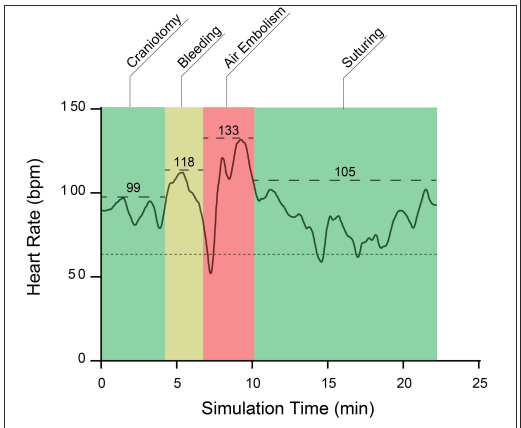


Figure 3: Representative heart rate (HR) tracing of trainee during simulation. The trainee's HR was elevated above published resting rates (64 bpm - small dash) for the entirety of the simulation. HR became elevated when simulated bleeding occured (yellow box) and again when a simulated air embolism occured (red box). Peak HR in each shaded region is written and indicated by large dash.

Faculty participant mean HR was lower than trainee HR (Figure 4A). All study participants experienced a signifcant rise in HR during the simulation (Figure 4B). Participants had a median of 2 tachycardic events during the simulation at various timepoints (Figure 4 C,D)

Figure 4

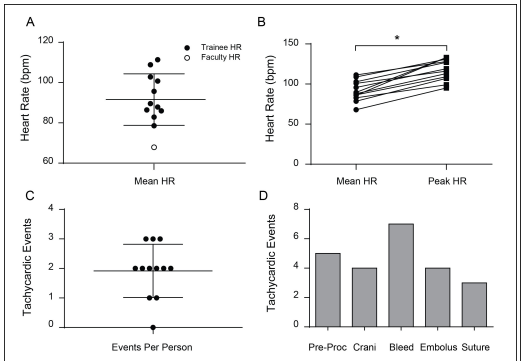


Figure 4: Simulated complications increase HR. A) Mean trainee HR was elevated compared to faculty member HR. B) HR was significantly elevated in study participants during the simulation. C) Study participants experienced a median 2 relative tachycardic events during the simulation. D) Relative tachycardia occured in varying points during the simulation. Relative Tachycardia = 2 s.d above mean HR, n = 12, * = p<0.001

Survey results indicate that the surgical simulation was of sufficient reality to allow the trainees to focus on the task at hand (Figure 5). Immersion was sufficient that trainees felt a sense of urgency at critical time points during the simulation. Opinions of the simulator's use as a training tool were favorable.

Figure 5

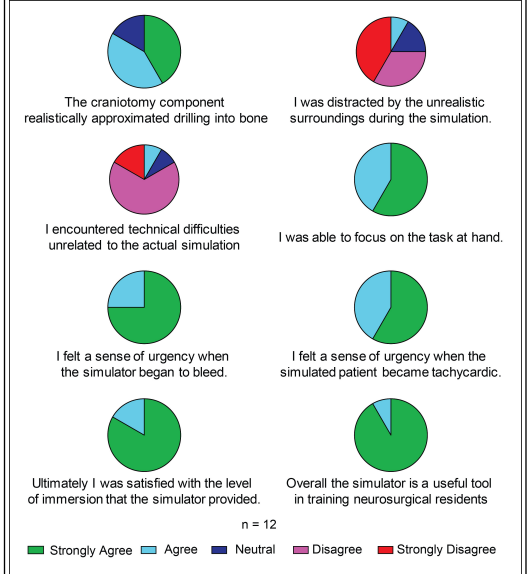


Figure 5. Survey results from study participants

Learning Objectives

Participants should be able to: 1) Describe the use of simulation in preparing residents for intraoperative emergencies. 2) Describe simulation of a dural venous sinus injury, and 3) Describe materials necessary to simulate cranial surgery

Conclusions

For our first demonstration of this modular and reconfigurable system, we simulated a superior sagittal sinus injury during surgery, complicated by an air embolism. HR and survey data indicate that the simulator provides a combination of manual and cognitive stress that accurately recreates surgical complcations in the operating suite. This simulation provides hands-on training designed to stress, test, and teach the resident without risking patient injury.

References

Resting Pulse Rate Reference Data for Children, Adolescents, and Adults: United States, 1999–2008 Ostchega Y, Porter KS,Hughes J, et al. Division of Health and Nutrition Examination Surveys issue 41 Aug 2011