A Mixed Simulator for Ventriculostomy Practice

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Introduction

- During bedside ventriculostomy, a catheter is inserted in a brain ventricle, without imaging guidance, to drain fluid.
- Neurosurgeons rely on anatomical landmarks and heuristics to establish the entry point at the skull and a 3D mental model of the brain to safely and efficiently steer the catheter tip to a ventricle.
- We designed a mixed simulator to provide practice to novice neurosurgeons to facilitate placing the catheter tip in the ventricle in one pass without striking undesired inner brain components.

Methods

- A mixed simulator, as the name implies, seamlessly mixes physical and virtual components in a single simulator.
- In the case of the ventriculostomy simulator, we physically modeled the scalp, skull (including the harder inner and outer tables), dura, facial features (including anatomical landmarks) and the feel of inserting a catheter through brain matter.
- The remainder of the simulator (inner and outer brain) was virtually modeled and registered to the physical component (the skull) with sub-millimeter accuracy.
- The 3D model for the skull and the brain (outer and inner brain) came from a CT scan and MRI scan respectively of an actual human.
- Over 2 days, the individual inner brain components (ventricle, caudate, brainstem, etc.) were manually dissected by a NS resident into separate 3D virtual objects.
- We converted the CT scan of the skull to a 3D model that was then used to create a physical, full scale, anatomically correct 3D model of the skull via a fast prototyping machine, aka a 3D printer (zPrinter 310, Z Corporation, Rock Hill, SC).
- The needle tip and the catheter stylet tip were instrumented with magnetic sensors tracked in real time by a 3D tracking system (Ascension Technology Corp., Burlington, VT) relative to the virtual 3D structures of the inner brain.
- We implemented a scoring algorithm to automatically score performance at the end of a training session and a capture and replay function to facilitate after action review (debriefing).
- The simulated skull is actually drilled using the hand drill and other tools provided in a ventriculostomy kit (Bactiseal EVD Catheter set, 82-1745, Codman & Shurtleff, Inc., Raynham, MA). We designed and built scalp, skin and dura inserts that are used for right and left entry and then discarded.

Results

The simulator (Figure 1) was used by more than 70 attendees over three days at the annual meeting of the American Association of Neurological Surgeons (AANS) in April 2011 and was well received. A study was conducted during that AANS meeting and a manuscript describing the results of the study is being prepared. Additionally, the simulator is being used to train neurosurgery residents at the University of Florida. A video of the ventriculostomy simulator can be viewed at http://simulation.health.ufl.edu/simulation/ventric_sim.wmv

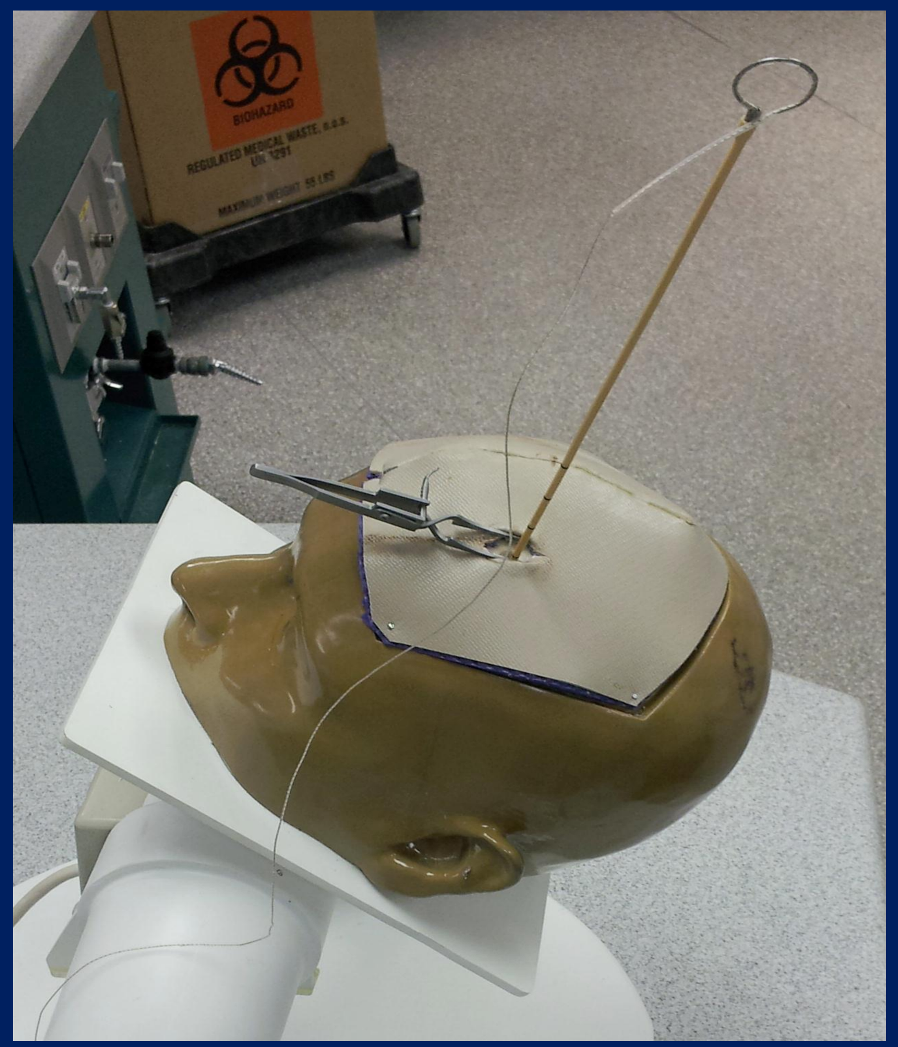

Figure 1. The mixed reality ventriculostomy simulator; a catheter stylet tracked in 3D space is inserted via a hole drilled by the learner through a disposable skull insert and steered to the ventricle.

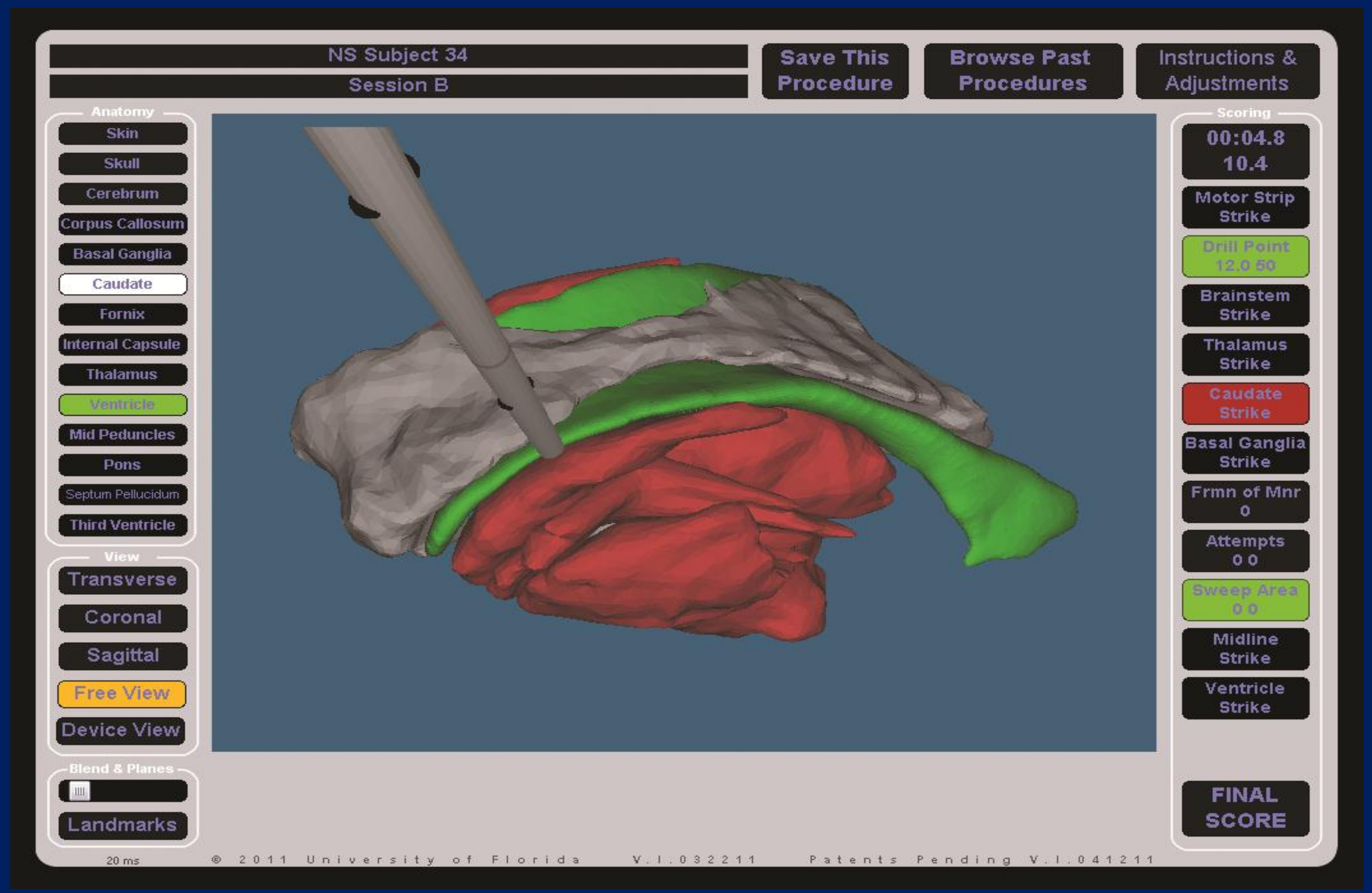

Figure 2. The virtual soft tissues (ventricles, caudate, brainstem and other inner brain components) are displayed collocated to a virtual representation of the physical catheter/stylet. The scalp, skull and outer brain opacity have been set by the instructor to transparent, in this view.

Conclusions

The simulator has been successfully demonstrated at two other meetings (Society of Neurosurgeons Annual Meeting, Portland, OR; Society of Neurosurgeons Boot Camp, Atlanta, GA) beyond AANS by non-technical team members, leading us to conclude that the simulator has reached a desirable "turnkey" status, i.e., compact, robust and intuitive enough that it can be unpacked, set up, operated, dismantled and re-packed by a single, non-technical person without assistance from technical personnel.

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