A Virtual Surgical Environment for Rehearsal of Tympanomastoidectomy

Sonny Chan, Peter Li, Joseph Lee, Kenneth Salisbury, and Nikolas Blevins
Biorobotics Laboratory & Department of Otolaryngology, Stanford University

Purpose

Despite the availability of high-resolution 3D medical imaging, today’s surgeon still faces difficulties in synthesizing these data into a practical conceptual model that can accurately predict what will be encountered intraoperatively. The main challenges include:

• mentally co-registering multi-model volumetric data from different studies
• formulating a 3D representation of the patient to see anatomic relations
• predicting how removal of tissues will affect subsequent exposure

Our goal is to create a virtual environment that can quickly incorporate routine clinical studies, enabling real-time preoperative assessment. Tympanomastoidectomy is a procedure that can benefit from this technology, and we have selected it to study the development of our virtual environment.

Materials & Methods

We collected data from 8 candidates for tympanomastoidectomy, performed image processing to construct computational models for simulation, and developed a virtual surgical environment with interactive visual and haptic feedback to enable preoperative assessment of the patient data.

MR imaging with a PROPELLER sequence shows a hyperintense region on patients with cholesteatoma. Registration with the CT localizes the cyst within the temporal bone. Avizo® software was used to segment and create models of additional anatomic structures relevant to the surgical procedure.

Patient-specific anatomical models are rendered in real-time and composited with a volume rendering of the bone tissue from the CT data using a ray-casting approach implemented on commodity graphics processors (GPUs).

A model of a virtual surgical drill allows the surgeon to interact with and manipulate the virtual patient. A novel haptic rendering algorithm computes force feedback through a SensAble Phantom Omni® haptic interface, allowing for stable and realistic haptic interaction with the patient’s anatomy.

Results

With intraoperative video as a reference, we attempted to reproduce portions of the mastoidectomy procedure in the virtual surgical environment on the same patient. We were able to establish strong correlations between the anatomical structures and the location of the cholesteatoma. Real-virtual image pairs from two select patients are shown.

The virtual surgical environment software system was designed to be portable and cost-effective so that it can be adopted in any preoperative workflow. It can be run on modern commodity desktop or laptop computers with Windows, Linux, or Mac OS X operating systems.

Conclusion

Our system represents a preliminary step toward the use of a virtual environment to prepare for tympanomastoid surgery. It enables the relatively rapid integration of multi-modal imaging datasets, direct volume rendering, and a means of manipulating preoperative clinical data in a surgically relevant manner.

Future steps in our work with the virtual surgical environment include

• streamlining data processing, including segmentation and registration
• conducting an objective study to assess the utility of the system