Toward Patient-Specific Simulation of Endoscopic Sinus Surgery

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Purpose

Endoscopic sinus surgery is a technically challenging procedure with a high risk of complication due to:

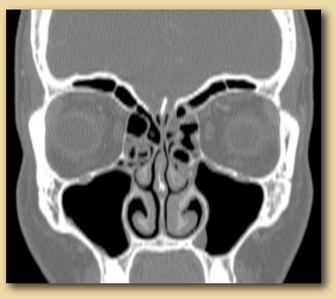
- limited field of view through surgical telescope
- constrained surgical workspace
- proximity to critical anatomical structures

A thorough understanding of the patient's specific anatomy before the operation is required to achieve a successful outcome.

Our goal is to provide a means for the surgeon to view and interact with pre-operative patient data in a surgically meaningful manner.

Materials & Methods

A virtual surgical environment capable of directly loading pre-operative CT image data to construct a virtual model of the patient was developed.

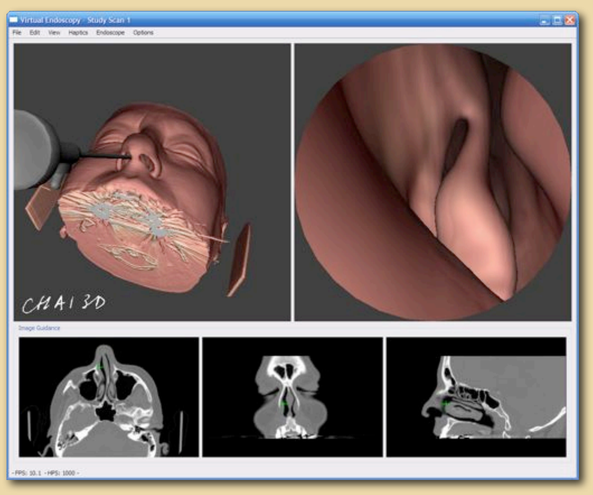


Pre-operative computed tomography imaging

High-resolution, multi-planar computed tomography (CT) images provide the surgeon with detailed anatomical information for pre-operative planning. Standard pre-operative sinus CT scans were obtained from three patients who underwent endoscopic sinus surgery.

Real-time volumetric rendering

Endoscopic views of the virtual patient from within the nasal cavity are rendered in real-time using a ray-casting approach implemented on commodity graphics processors (GPUs). A hybrid rendering approach incorporating both isosurface and direct volume rendering was chosen to reproduce the mucosal surface and the underlying bone and sub-mucosal tissue as accurately as possible.



Haptic interaction with virtual patients

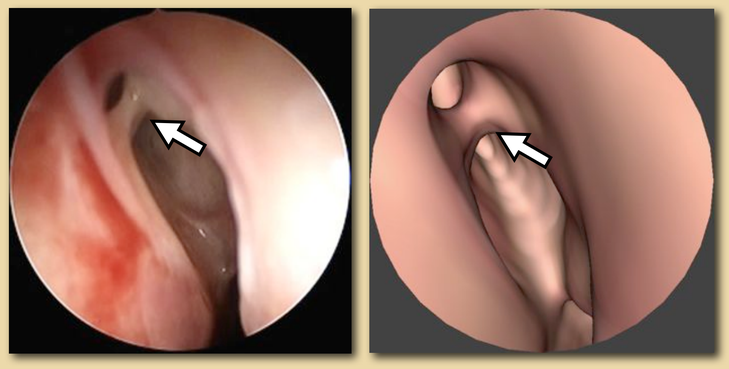
The surgeon can intuitively navigate the endoscope or surgical tool through the virtual patient's nasal cavity using a Sensable Phantom Omni® haptic interface device. Contacts between the tool and the patient's anatomy are detected, and resistive force feedback is rendered in real-time.

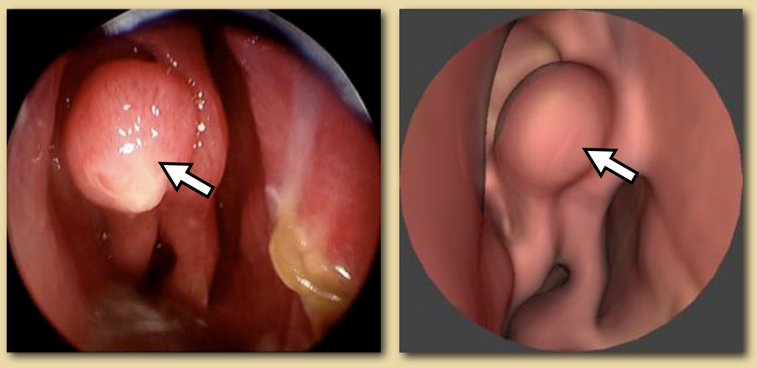
Results

The virtual surgical environment showed high-fidelity anatomical correlation between virtual and intra-operative findings for both patients. Structural similarities and correlation of anatomical landmarks were clearly identified in the comparison of the virtual (left) and intra-operative (right) endoscopic views.

Patient #1

Endoscopic views showing a mucosal band (arrow) on the lateral side of the middle turbinate in the right nasal cavity.



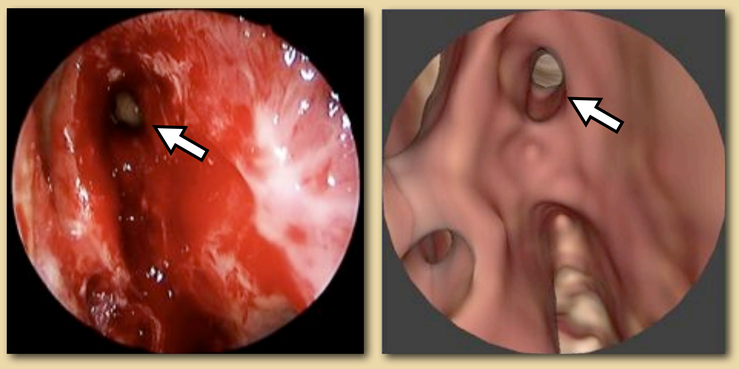


Patient #2

Endoscopic views of the right nasal cavity with an everted uncinate process (arrow) and partially resected middle turbinate.

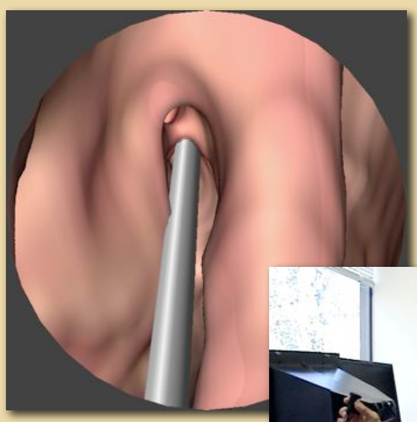
Patient #3

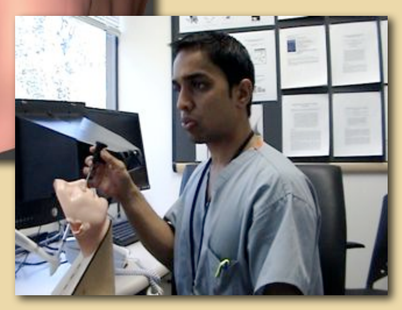
Endoscopic views of the frontal sinus outflow tract (arrow) during revision ethmoidectomy and frontal sinusotomy.



Haptic feedback constraining the position of the instrument was felt to be reasonably realistic in guiding the surgical tool.

Conclusion





Endoscopic sinus surgery can be a formidable challenge for the practicing rhinologist and a daunting task for residents in training. The ability to plan and rehearse the procedure on an accurate virtual model of the patient can allow the surgeon to be better prepared and more confident in the operating room. These capabilities will ultimately result in

- **fewer complications**
- **reduced operating times**
- **improved post-operative outcomes**