Image-Guided TransOral Robotics Surgery (TORS)

Wen P. Liu
Oropharyngeal Cancer

HPV-positive cases, which had made up just 16 percent of oral cancer cases in the 1980s, comprised more than 70 percent in the 2000s.

~Dr. Maura Gillison, Journal of Clinical Oncology
Oropharyngeal Cancer

**Traditional Standard of Care:**

- Radiation
- Chemotherapy
- Open Surgery
  - involves invasive techniques
  - long recoveries

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TransOral Robotic Surgery

*TORS has dramatically improved the way we treat head and neck cancer patients, completely removing tumors while preserving speech, swallowing, and other key quality of life issues. “*

~ Bert O’Malley Jr., MD, professor and chairman of Penn Medicines' Department of Otorhinolaryngology

(1) Decrease morbidity relative to open surgical procedures

(2) Decrease swallowing dysfunction relative to chemoradiation

(3) Improve access and “teachability” relative to Transoral laser microsurgery (TLM)

Credit: Weinstein; O’Malley, Penn Medicine
Benefits of TORS

• Avoidance of disfiguring mandibulotomy

• Minimization or elimination of need for chemoradiation therapy

• Avoidance of tracheostomy

• Quicker return to normal speech and swallowing

• Significantly less pain

• Decreased blood loss

• Shorter recovery time and hospital stay

http://wiki.uiowa.edu/display/protocols/Transoral+Robotic+Surgery
Contraindications

• Inability to adequately visualize anatomy to perform the diagnostic or therapeutic surgical approach transorally

• Unresectability of involved neck nodes

• Mandibular invasion

• Radiologic confirmation of carotid artery involvement

• Fixation of tumor to the prevertebral fascia

• Medialized carotid artery lying adjacent to tonsil (contraindication for radical tonsillectomy, not tongue base resection)

http://wiki.uiowa.edu/display/protocols/Transoral+Robotic+Surgery
SOLUTION: Image-Guided TORS

Augment the video scene with intraoperative images from cone-beam CT (CBCT) to improve navigation and patient safety by:

• Improving target resection

• Better delineation of critical structures
Preoperative Planning & Intraoperative Imaging

- **Advantages**
  - Up-to-date anatomical information
  - Assessment of surgical progress

- **Emerging Technologies**
  - CT, MR, ...
  - C-Arm Cone-Beam CT
  ~Conely, et al. Comparison of Intraoperative Portable CT Scanners in Skull Base and Endoscopic Sinus Surgery
  Skull Base Thieme eJournal 2011

Nithiananthan, SPIE (2010)
TORS CBCT Workflow

<table>
<thead>
<tr>
<th>Preoperative</th>
<th>Intraoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaging</td>
<td>Surgical Preparation</td>
</tr>
</tbody>
</table>

Conventional:
- **CT/MR**
- **Patient Prep**
- da Vinci Setup
- da Vinci

Experimental:
- **ITK**
- **Planned Data**
- **Patient Registration**
- **Endoscope Calibration**
- **CBCT**
- Demon
- Conventional + Augmented Display

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiological Technician</td>
<td>1 hour</td>
</tr>
<tr>
<td>Research Staff</td>
<td>0.5 hour</td>
</tr>
<tr>
<td>Surgical Technician</td>
<td>0.5 hour</td>
</tr>
<tr>
<td>Surgeon</td>
<td>0.25 hour</td>
</tr>
<tr>
<td>Research Staff</td>
<td>0.25 hour</td>
</tr>
<tr>
<td>Surgeon</td>
<td>Case Duration</td>
</tr>
</tbody>
</table>
Image-Guided TORS

- Challenges:
  - Cone-beam CT (CBCT) C-arm placement
  - Preoperative CT/MRI registration to Intraop CBCT
    - Metallic retractor artifact
  - Intraop CBCT registration to robot
  - Tool/camera tracking & registration update
  - Video overlay
Image-Guided TORS

• Challenges:
  – Cone-beam CT (CBCT) C-arm placement
Patient Positioning
Image-Guided TORS

- **Challenges:**
  - Preoperative CT/MRI registration to Intraop CBCT
    - Metallic retractor artifact
Retractors

Figure 9: Patient positioned with assistance at bedside and at the head of the bed

Figure 10: Position of the cannula, camera and instrument arms relative to the mouth gag and oral cavity

Either the Intuitive Surgical high-magnification camera head (45° FOV) or the 3D HD system (Ikegami/Panasonic) is recommended for da Vinci TORS. This is because with the high-magnification cameras, you can maintain a close-up of the surgical site while avoiding instrument interference by pulling the endoscope tip back. If the Intuitive Surgical high-magnification camera head is used, be advised that the field of view is smaller (45° viewing angle versus 60° viewing angle for the Intuitive Surgical wide-angle camera head), which will require more camera rotation and movement during the case to visualize the target anatomy. The Ikegami camera system provides a wide 16-9 view and digital zoom without above-mentioned limitations.

Figure 11: FK retractor (Feyh-Kastenbauer system)

For base-of-tongue and tonsillar procedures, the mouth gag of choice is the Crow-Davis [Figure 12], with the FK retractor system being used occasionally to expose the portion of the tongue base adjacent to the vallecula.

Figure 12: Crow-Davis mouth gag with Davis-Meyer Tongue Blade

Before starting the da Vinci TORS procedure, there should be a final confirmation that the area of the laryngopharynx to be operated upon can be adequately visualized to perform the planned procedure. Depending on the individual exposure of the surgical field, the 0 degree endoscope is almost always inserted first to visualize the operative field; change to the 30 degree scope if and when it is necessary. The patient-side assistant can facilitate exposure with manual manipulation. [Figure 13]

Credit: Weinstein; O’Malley, Penn Medicine
Retractor
CT (Open) to CBCT (Open)

CT (Open)

CT Rigid

CT Demons

CBCT (Open)
CBCT (Open) to CBCT (Tongue Pulled)

CBCT (Open)

CBCT (Open) Rigid

CBCT (Open) Demons

CBCT (Tongue-Pulled)
### Demons Registration

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinus anatomy displaced</td>
<td>Neck flexion</td>
<td>Sinus inflammation; surgical access</td>
<td>Jaw flexion, nasal anatomy displaced</td>
</tr>
</tbody>
</table>

- **Pre Operative CT**
- **Intra Operative CBCT**
- **FOV & Deformation**
- **Difference Image**

In this study, thresholds were calculated using CBCT on a medical linear accelerator prototype C-arm, while those denoted "IGRT" were imaged with a Synergy XVI, Elekta Oncology, Stockholm, Sweden.

Cases denoted "IGS" were imaged using the Demons deformable registration for CBCT-guided therapy of the head and neck. An overview of the datasets is shown in Table I. The simulations examined a combination of simulations, cadaver studies, and real patient studies investigated the performance of the IIM approach in real data across a broad range of geometric variations ranging from fairly simple deformation to complex deformations ranging from fairly simple deformation to complex deformations across a broad range of intensity variations that could be exhibited under various conditions of CBCT imaging and the cadaver/cadaver/cadaver combination.

Thresholds were implemented using well studied techniques, e.g., weight loss or disease progression.

The effect of intensity mismatch on CT-CBCT registration was varied widely depending on various clinical conditions, tissue classes, and bone overlay on CT and soft tissue 1 and soft tissue 2.

The second row shows the preoperative CT overlaid on CT and the second the fixed image overlaid on CT. The third row illustrates the preoperative CBCT overlaid on CT and the fourth row shows the difference image following rigid registration.

F.

- **Medical Physics, Vol. 38, No. 4, April 2011**: Iterative intensity matching for CT-CBCT registration 1789

Image-Guided TORS - Data Flow

- Preop CT/MR
- Intraop CBCT
- Segment & Plan
- Updated Intra-operative Plan
- Register to da Vinci
- Overlay
- Video
Proposed Milestones

• **Milestone 1**: Jan 2012
  – Video-Overlay (phantom validation)

• **Milestone 2**: May 2012
  – CIS II - Retractor project
  – Explore Image Registration (Demons, B-Spline)
    • Tongue inserts
    • Video-overlay (cadaver validation)

• **Milestone 3**: September 2012
  – Explore video overlay
  – Explore da Vinci registration
Image-Guided TORS - Data Flow

- **Milestone 1 : Jan 2012**
  - Video-Overlay (phantom validation)

- Preop CT/MR
- Intraop CBCT
- Phantom CBCT

- Segment & Plan
- Tongue w/tumor

- Updated Intra-operative Plan

- Register to da Vinci
- Manual

- Overlay
  - Video
  - Rigid cisst/svl
Project: Video-CT Augmentation for Skull Base Surgery
References


• Iseli TA, Kulbersh BD, et al. Functional outcomes after transoral robotic surgery for head and neck cancer
