Patient Positioning in Head & Neck Treatment

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Learning Objectives
- Learn about essential components of Head & Neck Immobilization
- Learn about IGRT applications and limitations
- Suggest IGRT/ART strategies

Outline
- Immobilization
- IGRT
- Adaptive RT
Immobilization Principles for H&N

- Head
  - Aquaplastic mask
  - Cutout over eyes and mouth, bolus when needed
- Chin
  - Bite block
  - Mouth-piece
- Neck
  - Custom head mold
- Clavicles
  - Aquaplastic mask
  - Shoulder restraining methods

Thermal Mask Immobilization

Mouth-piece/Bite-block for Tongue/Chin Immobilization
How effective is an immobilization device? How much margin do we need if IGRT is not used

Civico

Orfit

Daily Setup Shifts Evaluated by IGRT

10/12 patients and 350 measurements
### Margin Considerations

<table>
<thead>
<tr>
<th>Direction</th>
<th>Civco Systematic Error (cm)</th>
<th>Orfit Systematic Error (cm)</th>
<th>Civco Random Error (cm)</th>
<th>Orfit Random Error (cm)</th>
<th>Civco Van Herk's Margins (cm)</th>
<th>Orfit Van Herk's Margins (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP</td>
<td>0.163</td>
<td>0.202</td>
<td>0.124</td>
<td>0.125</td>
<td>0.494</td>
<td>0.593</td>
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<tr>
<td>SI</td>
<td>0.156</td>
<td>0.122</td>
<td>0.156</td>
<td>0.117</td>
<td>0.499</td>
<td>0.387</td>
</tr>
<tr>
<td>ML</td>
<td>0.127</td>
<td>0.161</td>
<td>0.107</td>
<td>0.109</td>
<td>0.392</td>
<td>0.479</td>
</tr>
</tbody>
</table>

**Mask doesn’t properly fit**

**Planning CT** vs **Daily CT09**

**Measuring set up using MatriXX system**

- Base Frame
- 9° Wedge
- Foam Head Rest (Medium Density):
  - 1 to 6
  - B
  - C
  - F
- Energy: 6MV

Author: Luis Fong, Ph.D.
Mayo Clinic
Image Guidance Technologies for H&N IMRT

- Daily orthogonal KV x-rays
- Implanted fiducials and kV x-rays
- Optic-based surface alignment
- In-room volumetric imaging
  - Tomotherapy MV CT
  - Cone-beam CT (KV and MV)
  - kV CT-on-rails
  - MR (in development)

From IMRT to IGRT

Direct Portal Verification

To Isocenter Verification
What is the planning CT scan slice spacing in your practice?

1. 5 mm
2. 3 mm
3. 2.5 mm
4. 2 mm
5. < 1.5 mm
Traditional alignment assumes rigid body for the entire H&N region.

Can you combine multiple 2D ROI for a 3D ROI?

2D planar x-rays = volume alignment?

- 2 x 2D = 3D?

Voluntary Junction Shifting: Orthogonal KV Images

Setup Uncertainties In Head & Neck Treatment

Patient with Tongue Base Carcinoma
19 CT Scans over 47 Days

Daily Setup Uncertainties Captured by Orthogonal KV Images

2D vs. 3D Alignment
Weekly film discovered: IGRT is off?

Daily IGRT Reduces Margins by Half

- 28 consecutive patients
- 1013 CBCT scans
- Pre-alignment margins: ~ 4-5 mm
- Post-alignment margins: ~ 1.5 – 2.5 mm
- More margins may be needed for larynx cancers or patients with significant weight loss

Imaging Dose

Planning CT

CBCT “Standard Head” 0.4 cGy

Den et al., IJROBP v76 No. 5, 2010
3D IGRT Challenge

Which structure to align?
How to handle non-rigid setup error?

Examples of anatomy rotation between the planning CT (first row) and the daily CT (second row). The axial CT images shown on the left indicate a roll in the patient’s head; the coronal CT images on the right show jaw rotation of the spine column.

Change in the Neck Curvature

Planning CT

Daily Cone-beam CT with planning contour overlay

Setup uncertainties in sub-regions of H&N anatomy

Increased deformation with longer distances from the reference (C1-C3)

Histogram comparison of PPM measured random shift between stent group and non-stent group

Red: no mouth-piece
Blue: with mouth-piece

Impact of ROI Selection for Patient Setup

A Region-of-Interest based image guidance strategy is preferred

The selection of ROI depends on the clinical case

Anatomy Changes During Radiotherapy

Primary Tumor Response To RT


Kranen et al., IJROBP, V73, pp1566 (2009)

**PLANNING CT**

Significant Anatomic Variations

- **Planning CT**
- **During Treatment**

**C2-bone Setup and Anatomy Change**

Image-guided Adaptive Radiotherapy for H&N
Benefit of IGRT Alone

**PHYSICS CONTRIBUTION**

**PAROTID GLAND DOSE IN INTENSITY-MODULATED RADIOTHERAPY FOR HEAD AND NECK CANCER: IS WHAT YOU PLAN WHAT YOU GET?**

Jennifer C. O’Daniel, Ph.D., Adam S. Garden, M.D., David L. Schwartz, M.D., Il-Ho Wang, Ph.D., Kuan K. Ang, M.D., Ph.D., Amin A. Asaadi, M.D., David I. Rosenberg, M.D., William H. Morrison, M.D., Joshua A. Asper, F.A.A.C., and Li-Ping Chang, Ph.D.

- Parotid gland mean dose above the planned dose by 5 to 7 Gy in 45% of the patients
- Bone (C2) alignment led to reductions relative to BB alignment in 91% of patients (median, 2 Gy; range, 0.3–8.3 Gy).
- The parotid dose from bone alignment was still greater than planned (median, 1.0 Gy, p = 0.007). Neither approach affected tumor dose coverage.

Who is going to draw these contours in adaptive radiotherapy?

**What is Deformable Image Registration?**

- Geometric transformation that brings one image in precise spatial correspondence with another image.

Auto-Segmentation of H&N Anatomy

<table>
<thead>
<tr>
<th>Planning CT Image</th>
<th>Mid-Course CT Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning Contours</td>
<td>Deformed Contours</td>
</tr>
</tbody>
</table>
Planning contours were automatically transformed to subsequent CT images.

What are the benefits of adaptive replanning?

Replanning Challenges

Volume ↓ DVH ↑

Re-Plan Activities
Re-Plan for Fraction #11

Fraction #11: 1st replan

Original Plan Re-calculated on Fraction #11

Replan on Fraction #11 CT

Target Coverage is not a problem
Contra-lateral parotid can be reduced by replanning.

Replanning benefits both parotids.

Oral cavity.
Fraction #23: 2nd replan

1st replan re-calculated on Fraction #23
Replan on Fraction #23 CT

Tumor Progression During Treatment
Planning CT
2 weeks into treatment

Practical Issues in Adaptive RT
• How do you improve immobilization?

Mask is not fitting
Summary for H&N patients

- Setup uncertainties
  - Need to worry about residual setup error at different parts of the H&N anatomy
  - ROI-based alignment is strongly recommended
  - Immobilization technique is important to minimize non-rigid changes.
  - Systematic uncertainties appear to be larger than random setup uncertainties.
  - Offline correction strategy is beneficial.

- Image Guidance
  - 3D alignment can resolve out-of-plane rotations and 3D shifts of ROI better than 2D projection method

- Trends in volumetric and positional variations
  - Adaptive radiotherapy strategy

Acknowledgement

- MD Anderson H&N Team