Patient Positioning in Head & Neck Treatment

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Disclosure

- Sponsored Research: Varian
- Sponsored Research: Philips
- NIH Grant: Optimization of Proton Therapy
- CPRIT Grant: Advanced Volumetric Imaging and Adaptive RT for Lung Cancer

Learning Objectives

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

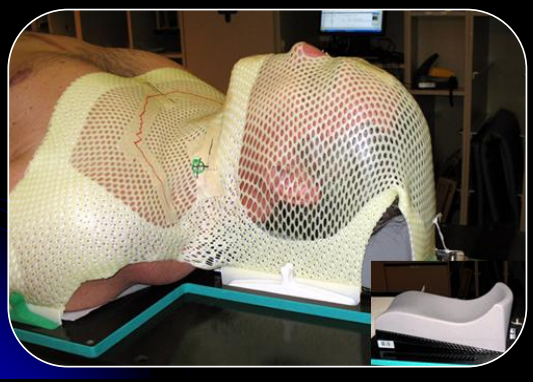
Outline

- Immobilization
- IGRT
- Adaptive RT

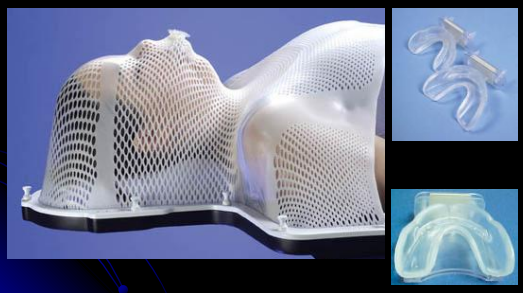
Immobilization Principles for H&N

- 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

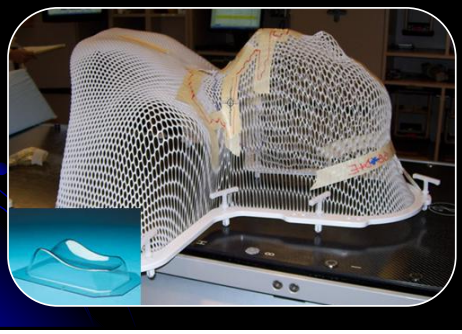


Mouth-piece/Bite-block for Tongue/Chin Immobilization

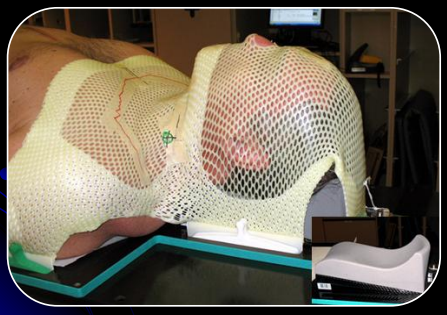


How effective is an immobilization device?
How much margin do we need if IGRT is not used

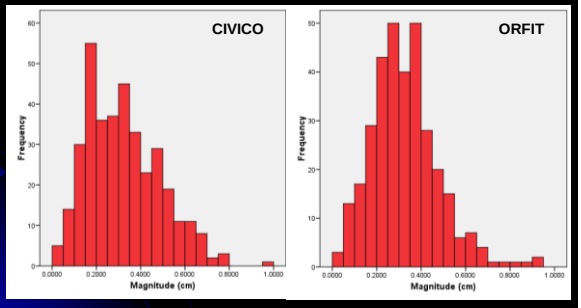
Civico



Orfit



Daily Setup Shifts Evaluated by IGRT

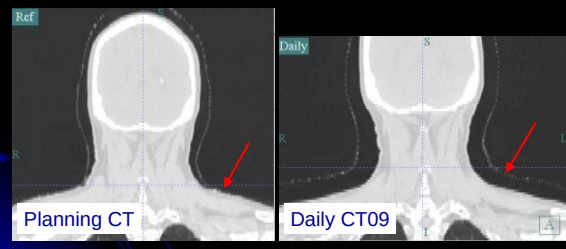


10/12 patients and 350 measurements

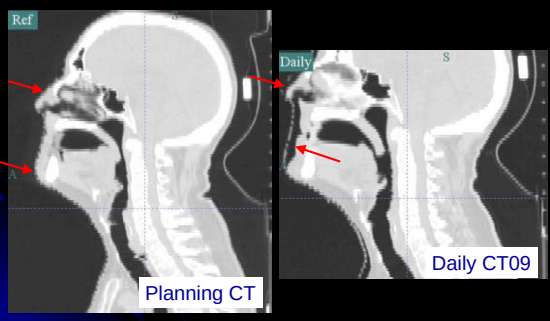
Margin Considerations

Direction	Systematic Error (cm)		Random Error (cm)		Van Herk's Margins (cm)	
	Civco	Orfit	Civco	Orfit	Civco	Orfit
AP	0.163	0.202	0.124	0.125	0.494	0.593
SI	0.156	0.122	0.156	0.117	0.499	0.387
ML	0.127	0.161	0.107	0.109	0.392	0.479

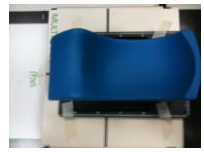
Mask doesn't properly fit

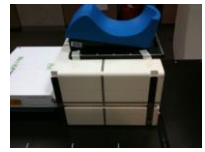


Mask doesn't properly fit



Measuring set up using MatriXX system





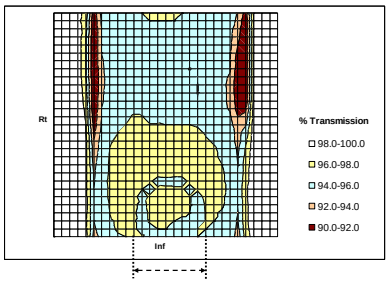
- Base Frame
- 9º Wedge
- Foam Head Rest (Medium Density):
  - 1 to 6
  - B
  - C
  - F

Energy: 6MV

Author: Luis Fong, Ph.D.

Mayo Clinic

No. 1 MatriXX Measurement



Transmission through Central Area

Average	95.8
Max	93.7
Min	97.0

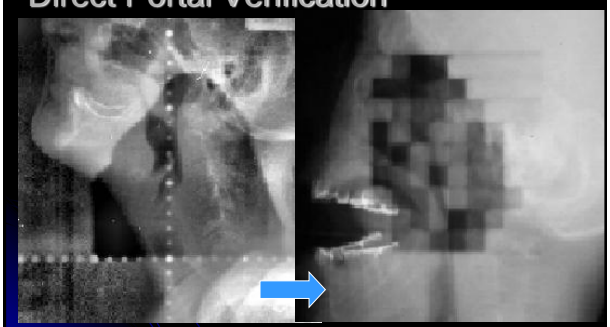
Author: Luis Fong, Ph.D. *Mayo Clinic*

From IMRT to IGRT

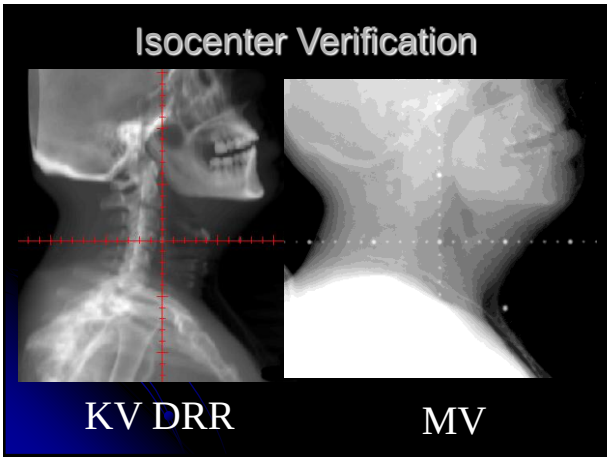
Image Guidance Technologies for H&N IMRT

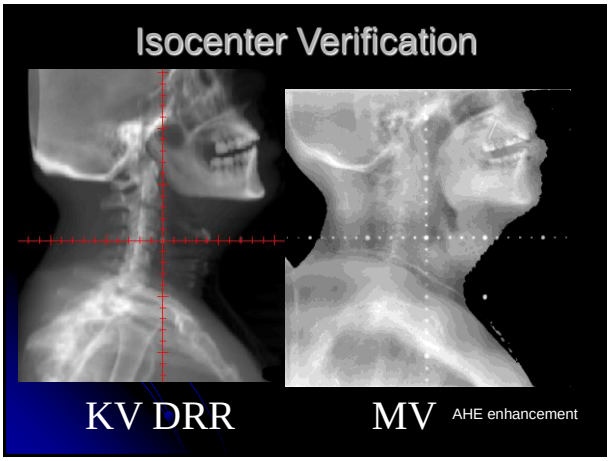
- Daily orthogonal KV x-rays
- Implanted fiducials and kV x-rays
- Optic-based surface alignment
- In-room volumetric imaging
  - Tomotherapy MV CT
  - Cone-beam CT (KV and MV)
  - kV CT-on-rails
  - MR (in development)

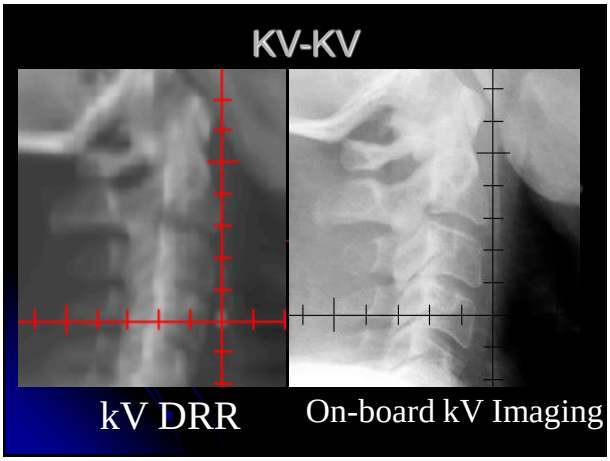
Direct Portal Verification



To Isocenter Verification





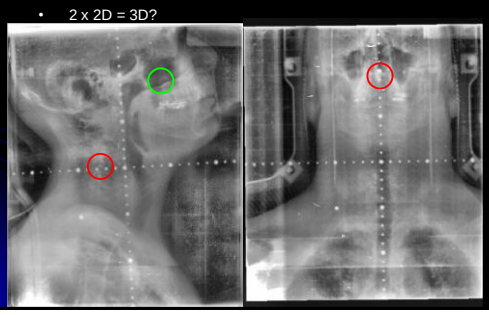


What is the planning CT scan slice spacing in your practice?

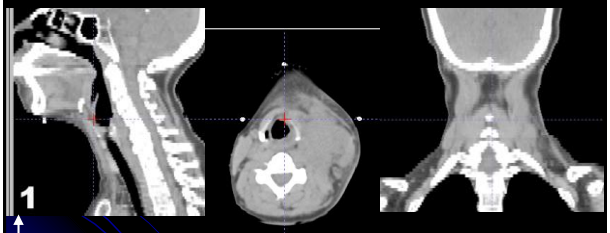
1. 5 mm
2. 3 mm
3. 2.5 mm
4. 2 mm
5. < 1.5 mm

2D planar x-rays = volume alignment?

- Traditional alignment assumes rigid-body for the entire H&N region
- Can you combine multiple 2D ROI for a 3D ROI?
  - 2 x 2D = 3D?



Setup Uncertainties In Head & Neck Treatment

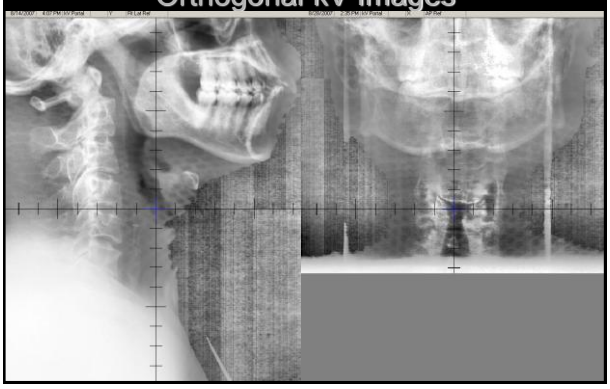


Elapsed Days

Patient with Tongue Base Carcinoma
19 CT Scans over 47 Days

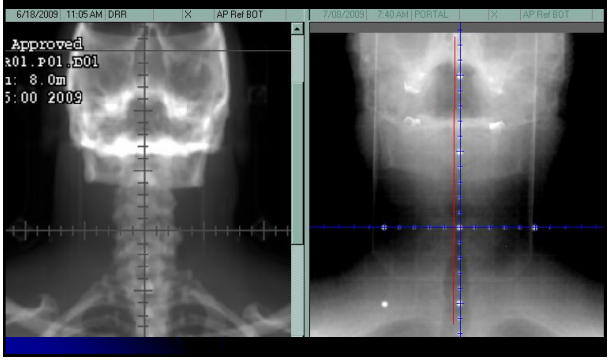
Lei Dong et al. (MDACC)

Daily Setup Uncertainties Captured by Orthogonal kV Images

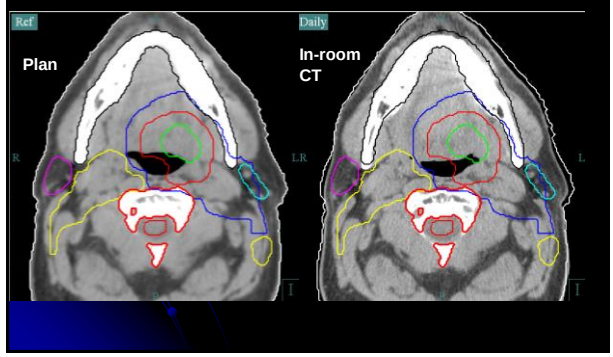


2D vs. 3D Alignment

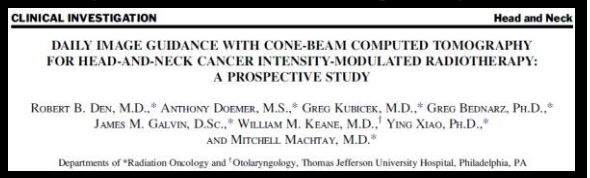
Weekly film discovered: IGRT is off?



3D vs. 2D



Daily IGRT Reduces Margins by Half


CLINICAL INVESTIGATION Head and Neck

DAILY IMAGE GUIDANCE WITH CONE-BEAM COMPUTED TOMOGRAPHY FOR HEAD-AND-NECK CANCER INTENSITY-MODULATED RADIOTHERAPY: A PROSPECTIVE STUDY

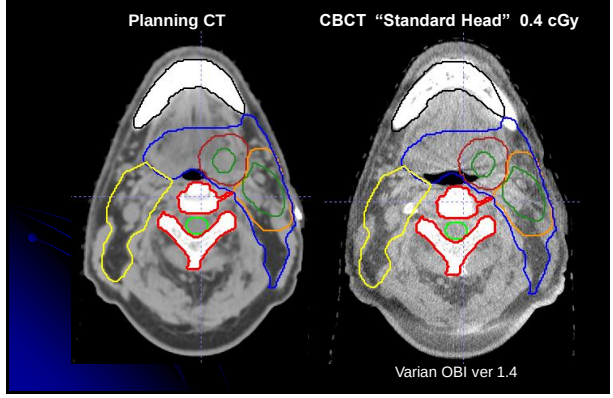
Robert B. Den, M.D.,* Anthony Doemer, M.S.,* Greg Kubicek, M.D.,* Greg Bednarz, Ph.D.,* James M. Galvin, D.Sc.,* William M. Keane, M.D.,† Ying Xiao, Ph.D.,* and Mitchell Machtay, M.D.*

Departments of *Radiation Oncology and †Otolaryngology, Thomas Jefferson University Hospital, Philadelphia, PA

- 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 larynx cancers or patients with significant weight loss

Den et al., IJROBP v76 No. 5, 2010

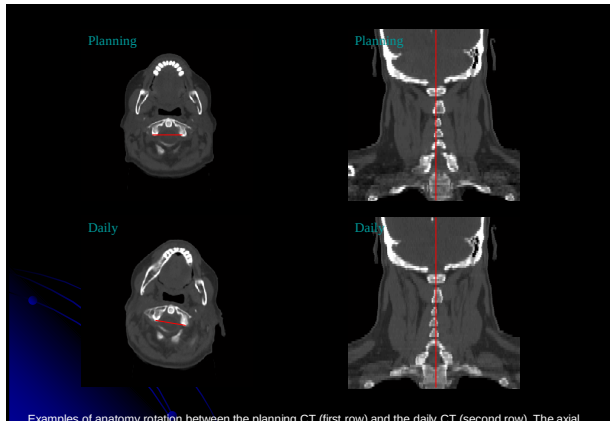
Imaging Dose



3D IGRT Challenge

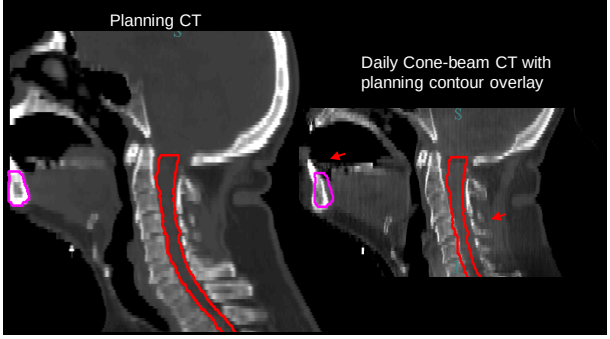
Which structure to align?

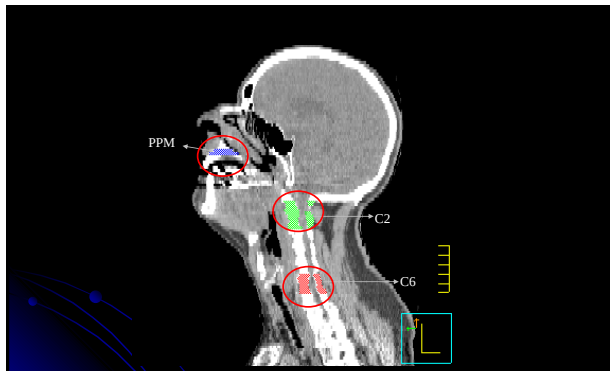
How to handle non-rigid setup error?



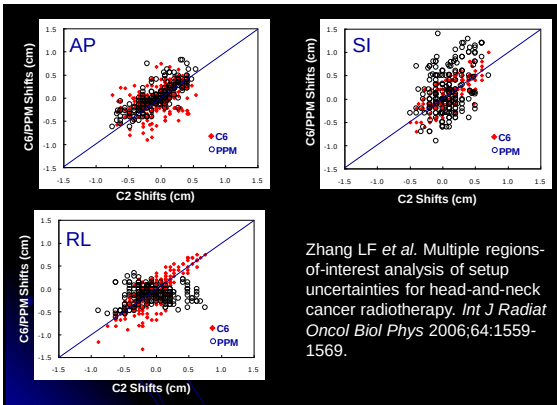
Examples of anatomy rotation between the planning CT (first row) and the daily CT (second row). The axial CT images shown on the left indicate a roll in the patient's head; the coronal CT images on the right show yaw (rotation of the spinal column).

Change in the Neck Curvature





L. Zhang et al. "Multiple regions-of-interest analysis of setup uncertainties for head and neck cancer radiotherapy," *Int. J. Radiat. Oncol. Biol. Phys.* **64** (5), 1159-69 (2006).

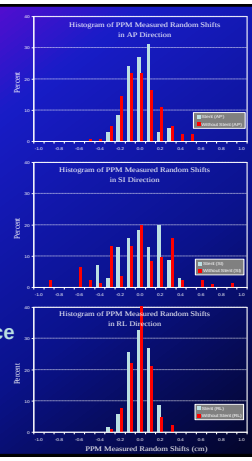


Zhang LF *et al.* Multiple regions-of-interest analysis of setup uncertainties for head-and-neck cancer radiotherapy. *Int J Radiat Oncol Biol Phys* 2006;64:1559-1569.

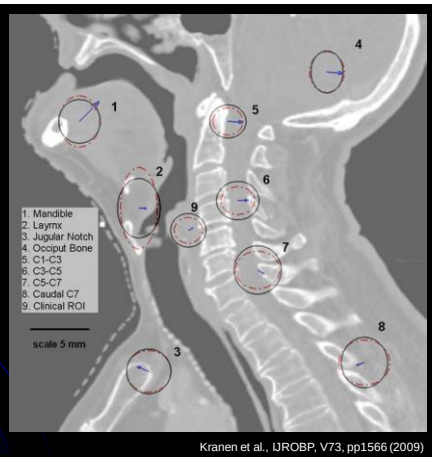
Histogram comparison of PPM measured random shift between stent group and non-stent group

Red: no mouth-piece

Blue: with mouth-piece

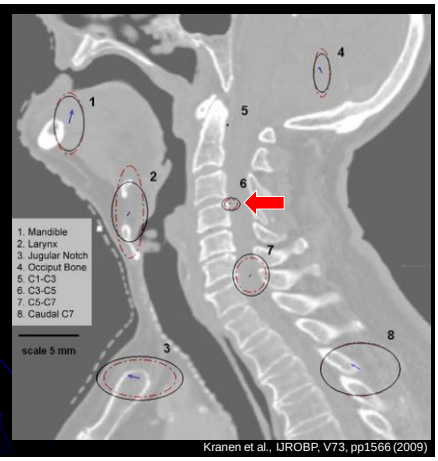


Setup uncertainties in sub-regions of H&N anatomy



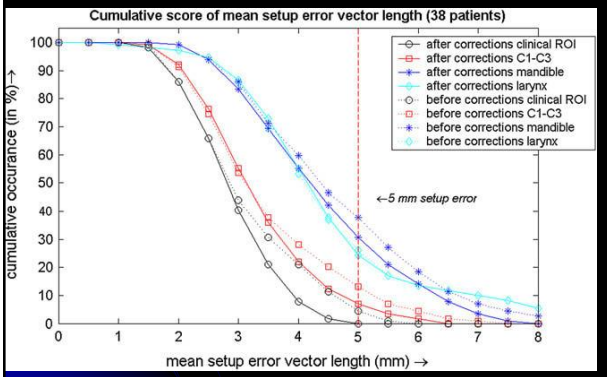
Kranen et al., IJROBP, V73, pp1566 (2009)

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



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

Impact of ROI Selection for Patient Setup

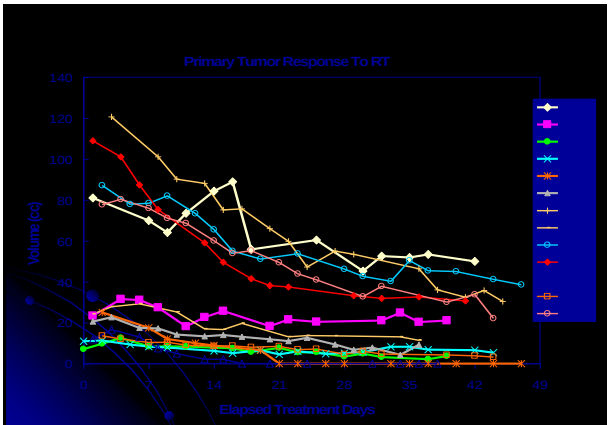


Kranen et al., IJROBP, V73, pp1566 (2009)

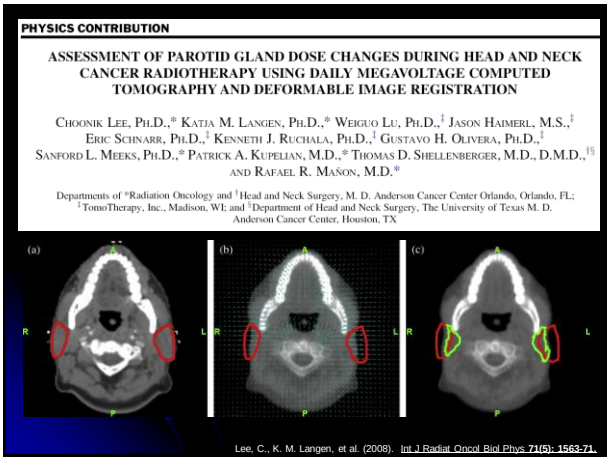
A Region-of-Interest based image guidance strategy is preferred

The selection of ROI depends on the clinical case

Anatomy Changes During Radiotherapy



Barker et al. *Int J Radiat Oncol Biol Phys* 2004; 59 (4):960-970.



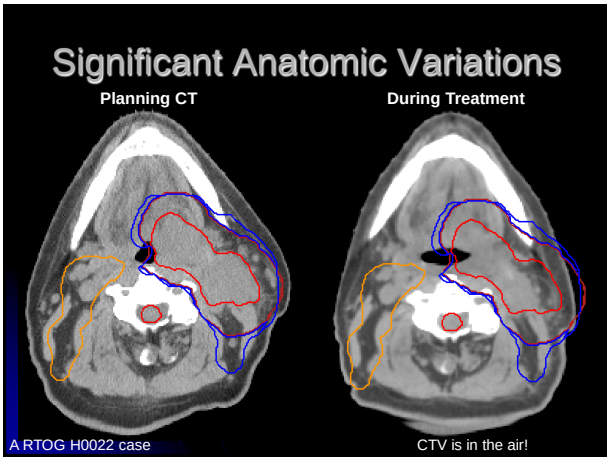
PHYSICS CONTRIBUTION

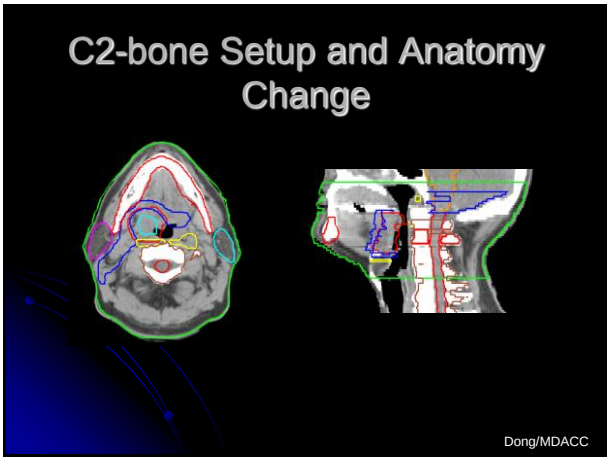
ASSESSMENT OF PAROTID GLAND DOSE CHANGES DURING HEAD AND NECK CANCER RADIOTHERAPY USING DAILY MEGAVOLTAGE COMPUTED TOMOGRAPHY AND DEFORMABLE IMAGE REGISTRATION

Choonik Lee, Ph.D.,* Katja M. Langen, Ph.D.,* Weiguo Lu, Ph.D.,† Jason Haimerl, M.S.,‡ Eric Schnarr, Ph.D.,‡ Kenneth J. Ruchala, Ph.D.,† Gustavo H. Olivera, Ph.D.,‡ Sanford L. Meeks, Ph.D.,* Patrick A. Kupelian, M.D.,* Thomas D. Shellenberger, M.D., D.M.D.,†§ and Rafael R. Mañon, M.D.*

Departments of *Radiation Oncology and †Head and Neck Surgery, M. D. Anderson Cancer Center Orlando, Orlando, FL; ‡TomoTherapy, Inc., Madison, WI; and §Department of Head and Neck Surgery, The University of Texas M. D. Anderson Cancer Center, Houston, TX

Lee, C., K. M. Langen, et al. (2008). Int J Radiat Oncol Biol Phys 71(5): 1563-71.





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.,† He Wang, Ph.D.,* Kian K. Ang, M.D., Ph.D.,† Anesa Ahamad, M.D.,† David I. Rosenthal, M.D.,† William H. Morrison, M.D.,† Joshua A. Asper, P.A.C.,† Lifei Zhang, Ph.D.,* Shih-Ming Tung, M.S.,* Radhe Mohan, Ph.D.,* and Lei Dong, Ph.D.*

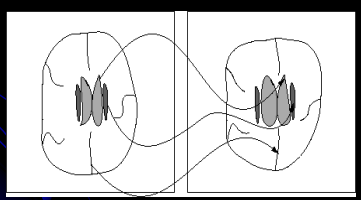
- Parotid gland mean dose above the planned dose by 5 to 7 Gy in 45% of the patients
- Bone (C2) alignment led to reductions relative to BB alignment in 91% of patients (median, 2 Gy; range, 0.3–8.3 Gy).
- The parotid dose from bone alignment was still greater than planned (median, 1.0 Gy, p = 0.007).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

O'Daniel et al. IJROBP vol.69 No.4 (2007)

Who is going to draw these contours in adaptive radiotherapy?

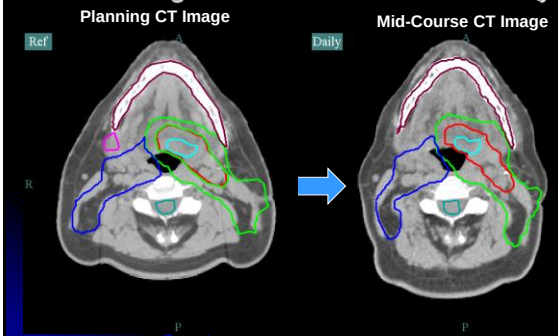
What is Deformable Image Registration?

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



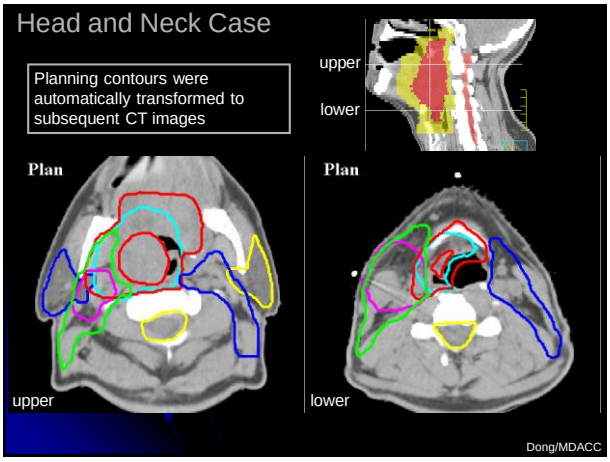
Registration

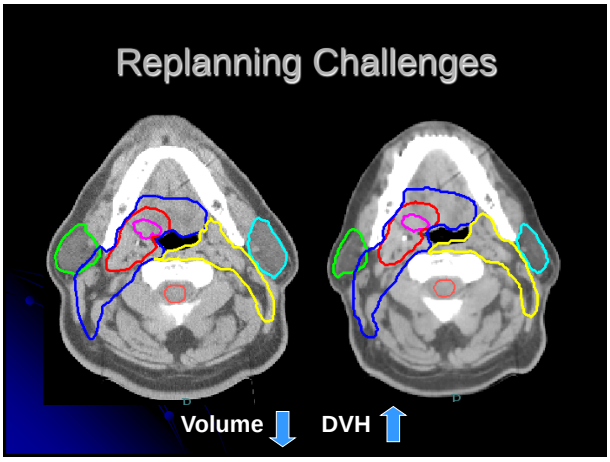
Auto-Segmentation of H&N Anatomy



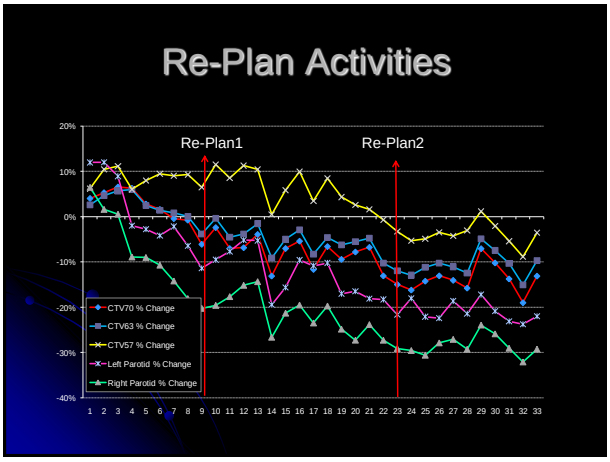
Planning Contours

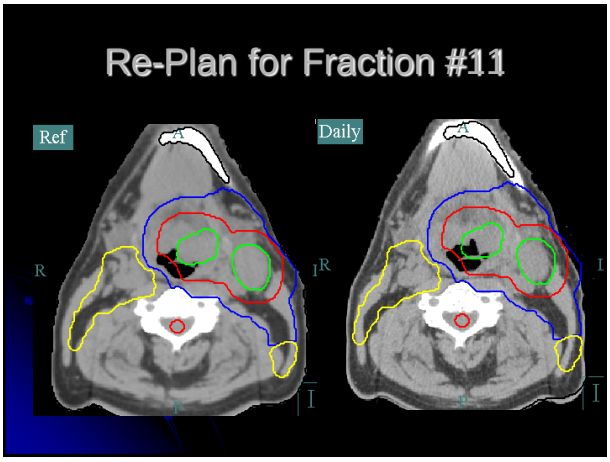
Deformed Contours

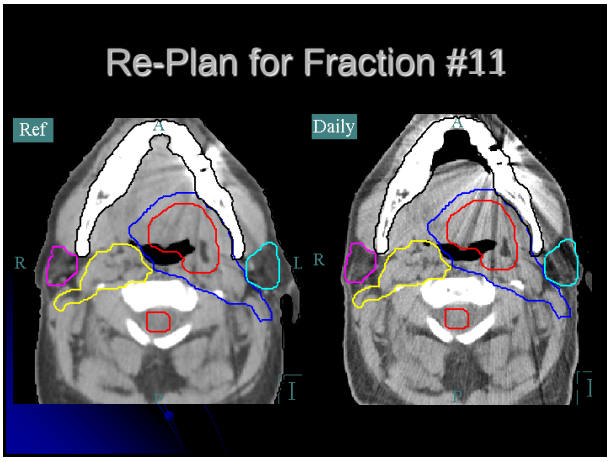


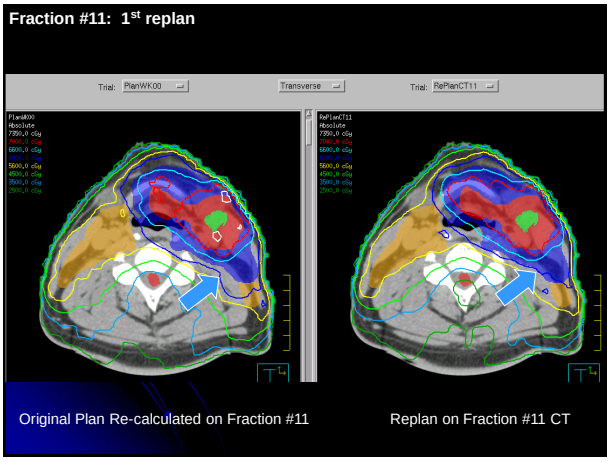


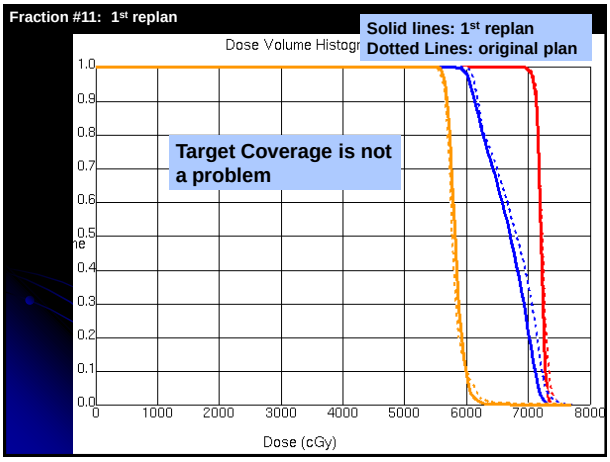
What are the benefits of adaptive replanning?

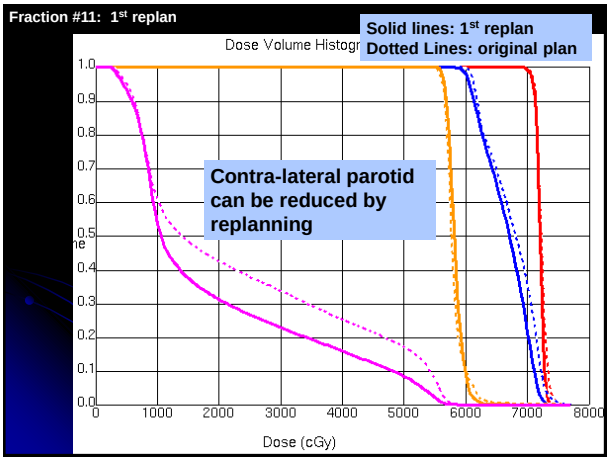


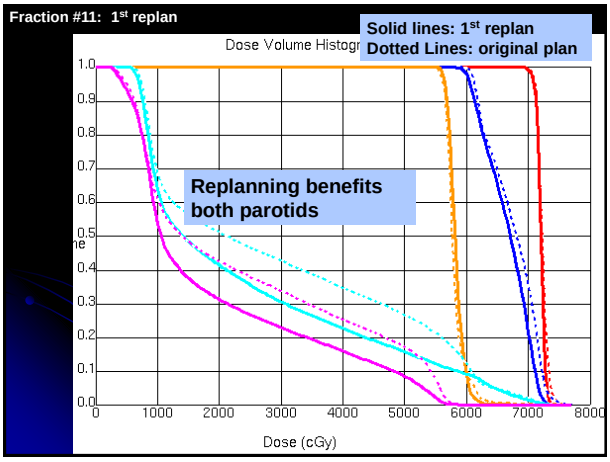

Re-Plan for Fraction #11
Ref
Daily

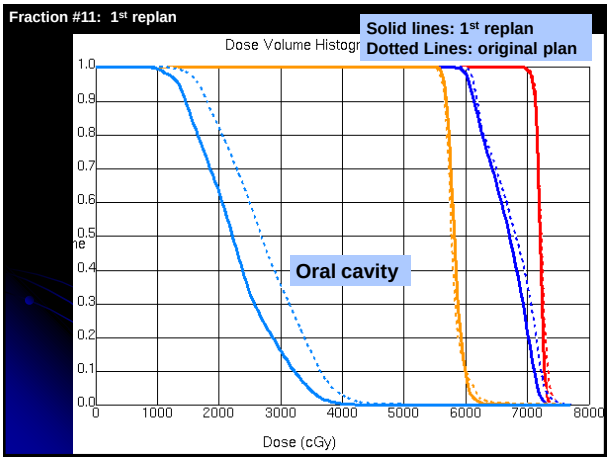

Re-Plan for Fraction #11
Ref
Daily

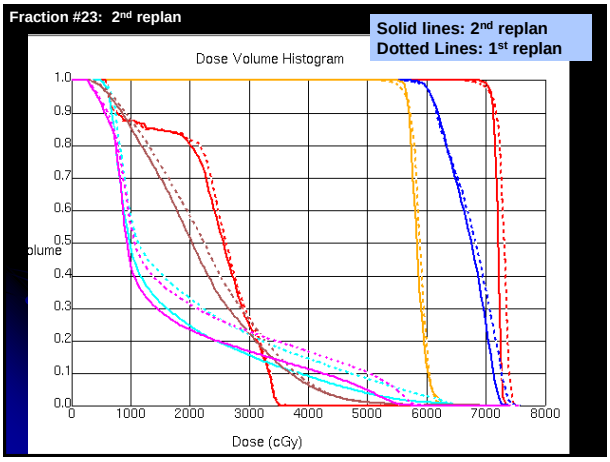

Fraction #11: 1st replan
Original Plan Re-calculated on Fraction #11
Replan on Fraction #11 CT

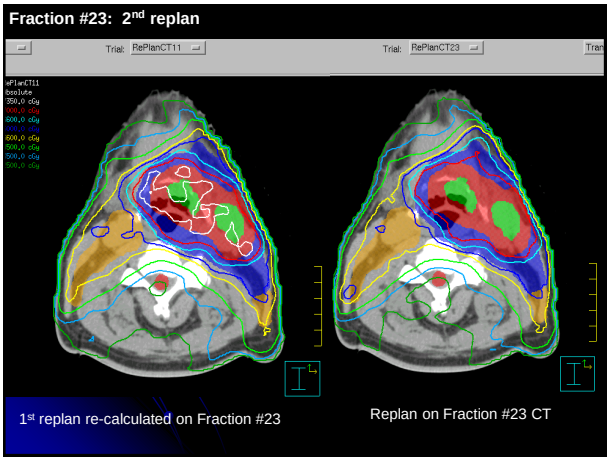

Fraction #11: 1st replan
Solid lines: 1st replan
Dotted Lines: original plan
Target Coverage is not a problem
Dose Volume Histogr
Dose (cGy)

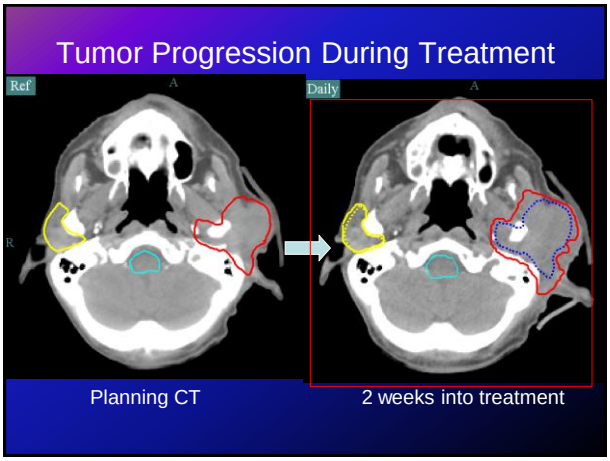

Fraction #11: 1st replan
Solid lines: 1st replan
Dotted Lines: original plan
Dose Volume Histogr
Contra-lateral parotid can be reduced by replanning
Dose (cGy)


Fraction #11: 1st replan
Solid lines: 1st replan
Dotted Lines: original plan
Dose Volume Histogr
Replanning benefits both parotids
Dose (cGy)


Fraction #11: 1st replan
Solid lines: 1st replan
Dotted Lines: original plan
Dose Volume Histogr
Oral cavity
Dose (cGy)


Fraction #23: 2nd replan
Solid lines: 2nd replan
Dotted Lines: 1st replan
Dose Volume Histogram
Dose (cGy)

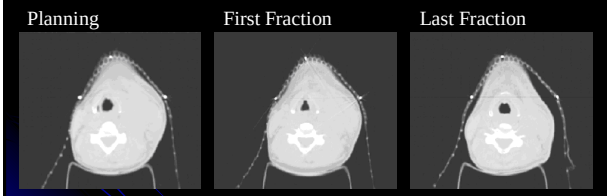


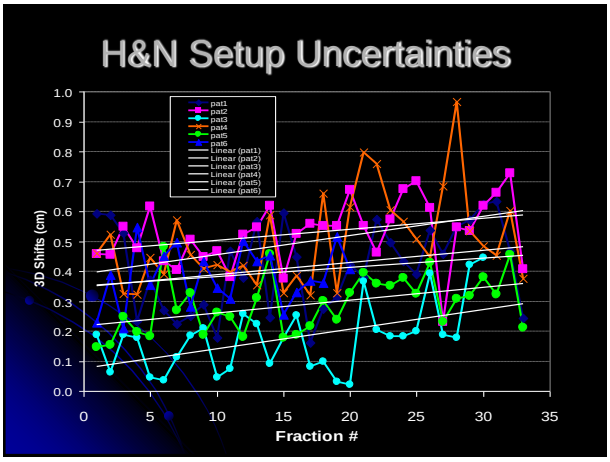


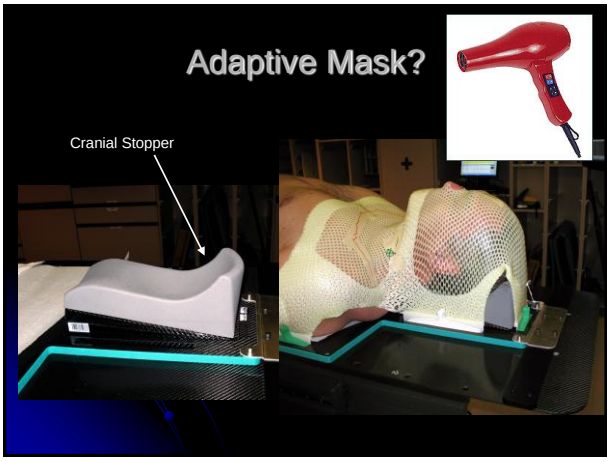
Mask is not fitting

Practical Issues in Adaptive RT

- How do you improve immobilization?







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