Imaging and Treatment Planning for Adaptive Radiotherapy in the Head and Neck

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Educational Objectives:

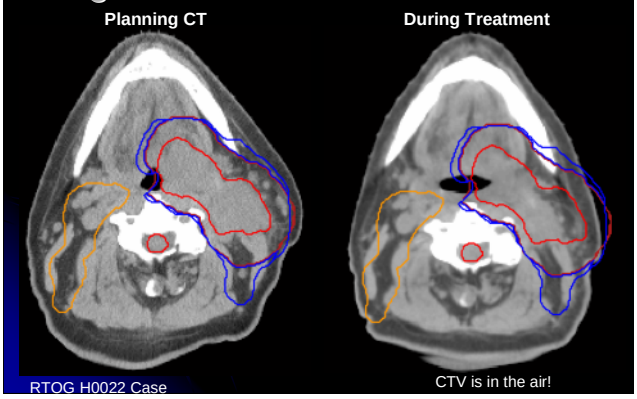
- Understand when re-planning is necessary and the level of image quality required for re-planning
- Understand the accuracy achievable and validation methods for deformable registration techniques used to relate in-room volumetric imaging to the planning dataset.
- Discuss dose accumulation, including methods for handling volume reduction and QA
- Understand the clinical significance of adaptive planning with regards to reported results to date and potential future results

Concept of Treatment Planning

Goal: To design a treatment plan based on an anticipated patient treatment

- **Requirements**
  - **Accurate model of the patient**
    - **CT or 4DCT of the patient in treatment position**
  - **Accurate margin prediction**
    - **Balance of risk and benefit**
  - **Presentation of simulation results**
    - **DVHs, Isodose lines**

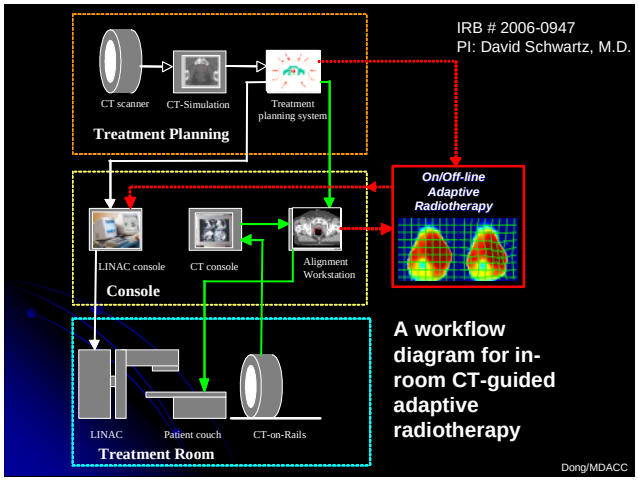
Significant Anatomic Variations



A single plan designed before treatment is insufficient to describe the actual **delivered doses**, and often leads to **suboptimal** treatment.

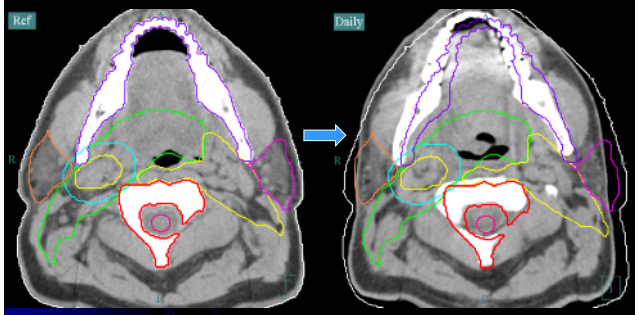
Image Guidance vs. Adaptive RT

- "Image Guidance" is commonly referred to a process to re-position the patient without modifying the initial treatment plan
- Adaptive RT involves the modification of the initial plan, including
  - Changing beam apertures or intensity patterns
  - Modifying original prescriptions
    - Require additional target information



A workflow diagram for in-room CT-guided adaptive radiotherapy

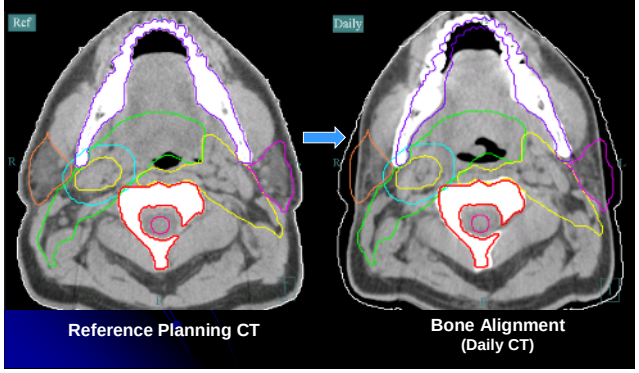
Treatment Strategy – Conventional



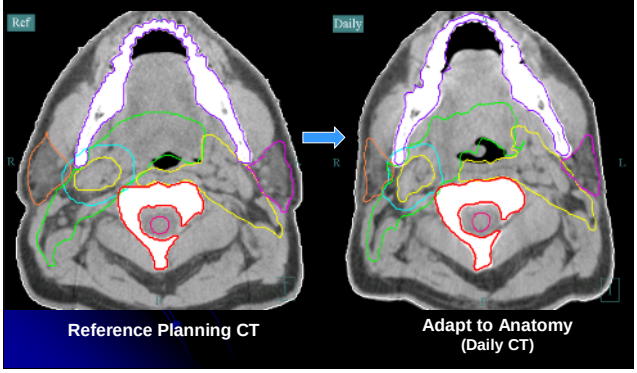
Reference Planning CT

Mask Alignment (Daily CT)

Treatment Strategy - IGRT



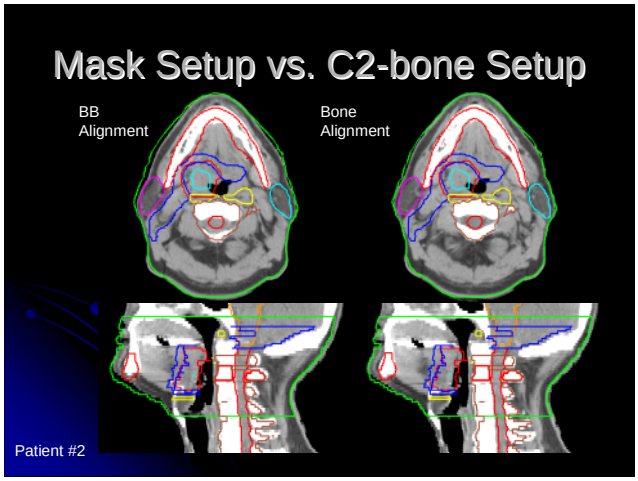
Treatment Strategy – IGART



Study Goals

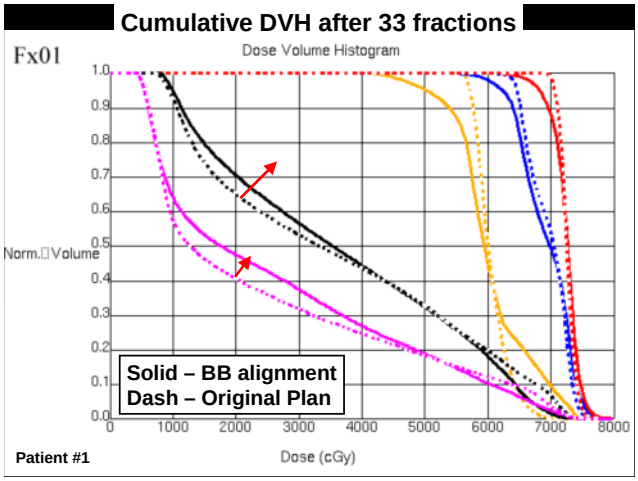
- Develop a practical procedure for IGART
- Evaluate the dosimetric benefits of a hybrid (on-line image guidance + off-line adaptive) approach for head & neck radiotherapy
- Evaluate clinical workflow and practical aspects of ART in a prospective trial
- Evaluate the improvement in outcome

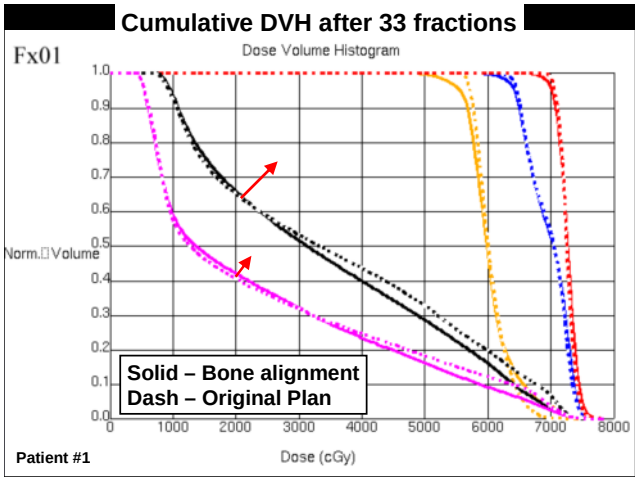
Daily Image Guided Setup



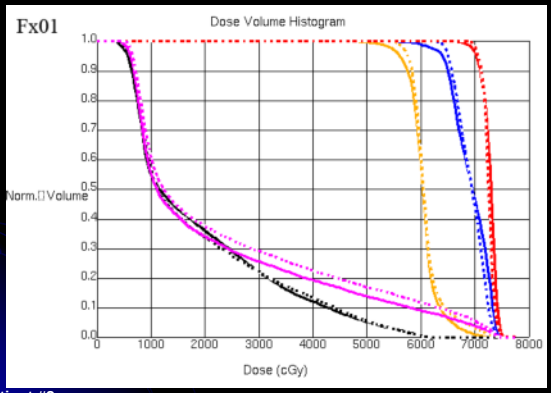
Retrospectively evaluating Cumulative Dose Distributions Fraction-by-Fraction

Planned vs. Delivered



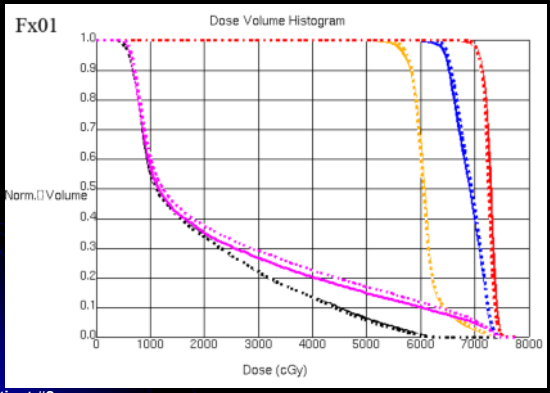


BB (skin mark) Setup



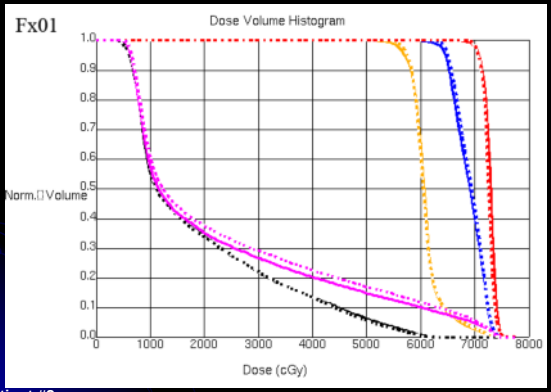
Patient #2

Bony Setup (IGRT)



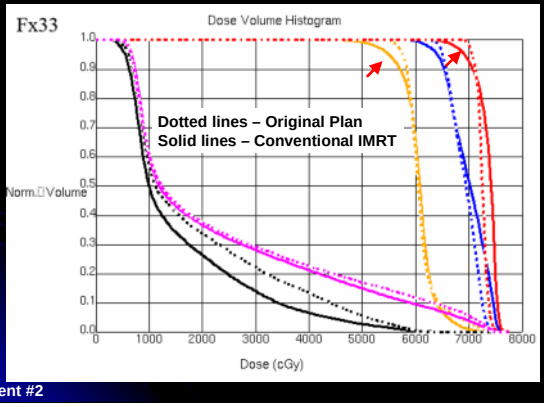
Patient #2

Bone Setup+Replan (ART)



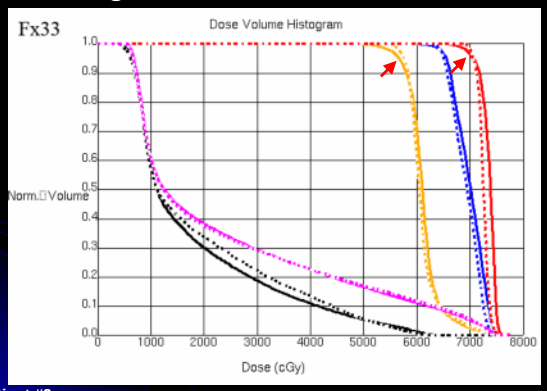
Patient #2

Mask-alignment at the end of treatment



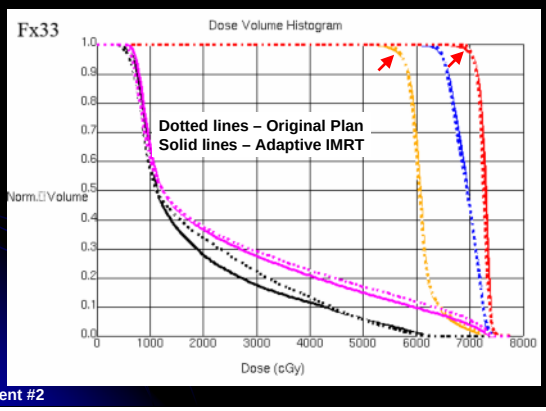
Patient #2

Bone-alignment at the end of treatment



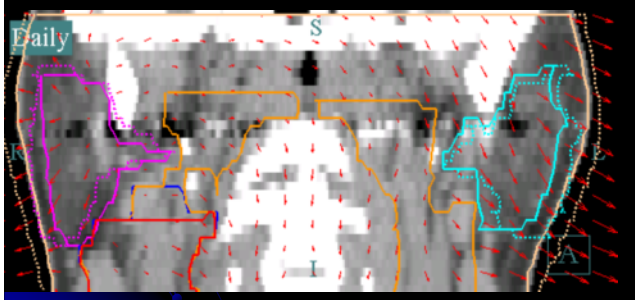
Patient #2

Adaptive Treatment at the end of treatment



Patient #2

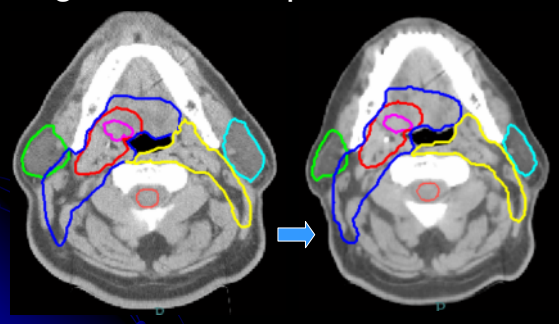
Why parotid dose was lower?



Patient #2

Auto-segmentation for adaptive replanning

Adaptive RT requires auto-segmentation – practical reasons

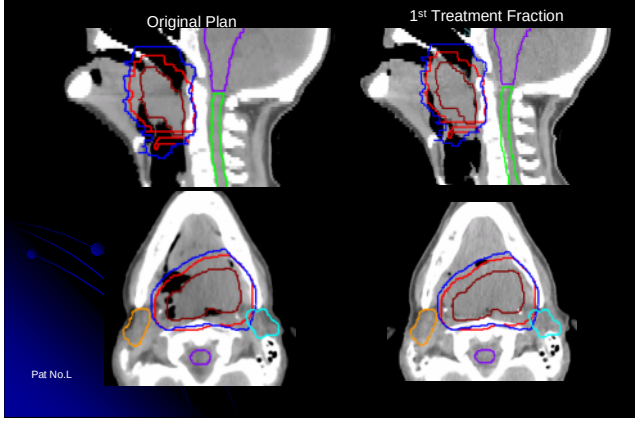


Early Results

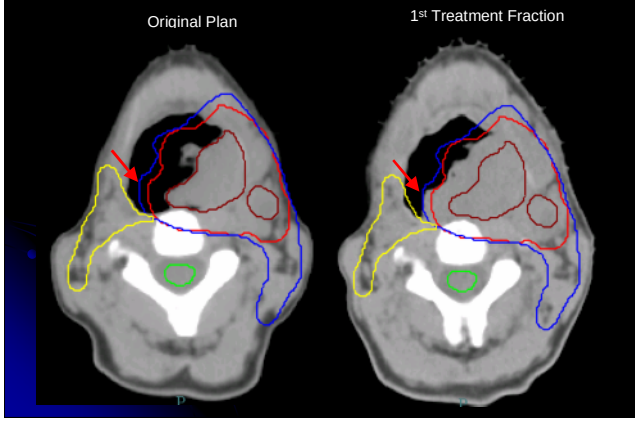
- 17 protocol patients +3 off-protocol
- Median 1st replan: 16th fraction
- Parotid changes at 1st replan: -16%
- CTV changed at 1st replan: -4%

- 4/17 had 2nd replan with a median fraction at Fraction 19
- Average parotid was changed to -20%
- Average CTV was changed to -8%

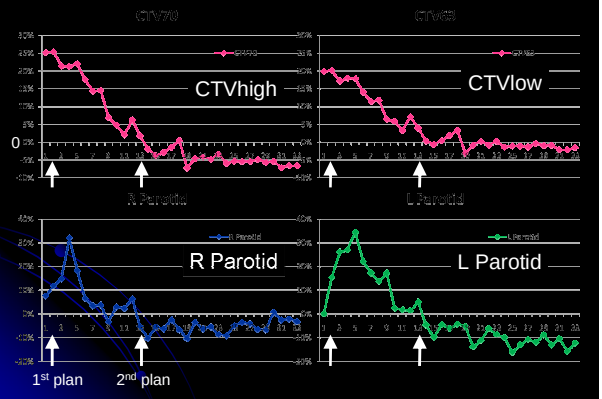
Early Adaptation – Fraction #1!



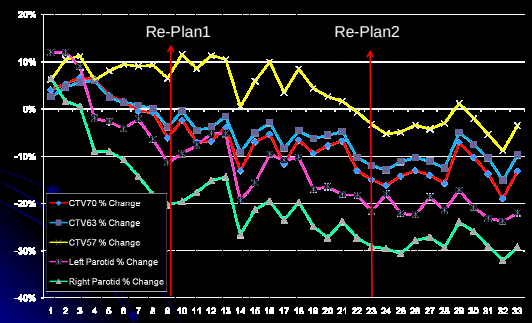
Early Replan – Fraction #1!



Early Adaptive Replan Case

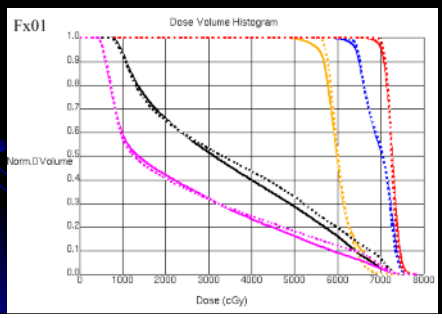


An Example

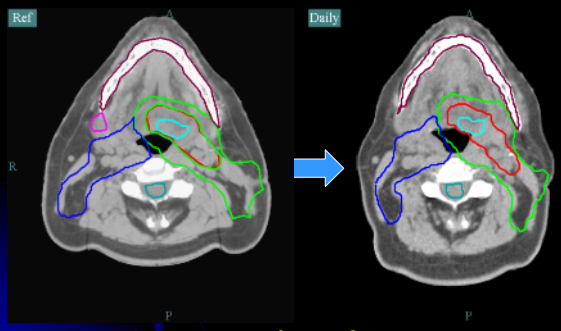


Practical Issues in Adaptive RT

- What is the trigger point for replanning?



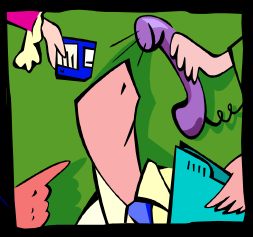
How to evaluate and approve these deformed contours?



Auto-Segmentation of H&N Anatomy

Practical Issues in Adaptive RT

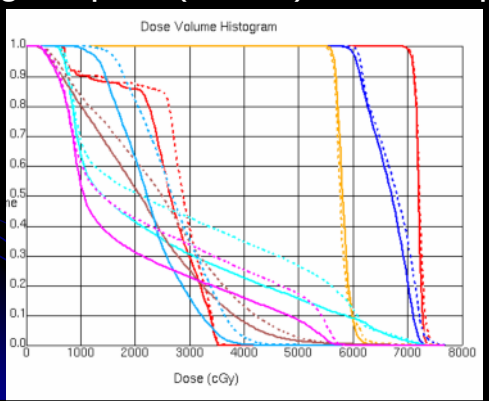
- Where do you find a physician to review your plan?



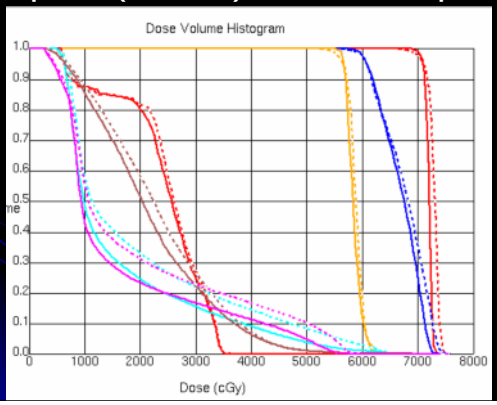
Practical Issues in Adaptive RT

- Where do you find a physician to review your plan?

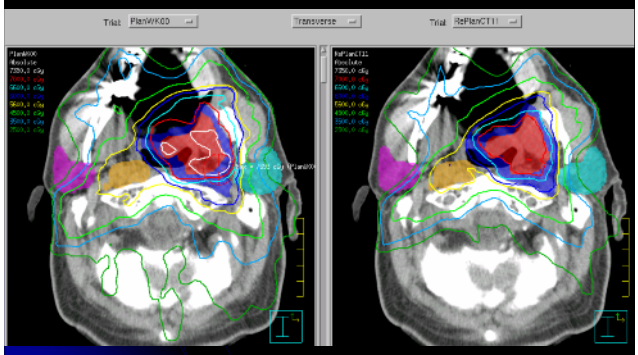
Original plan (dotted) vs. 1st Replan



1st plan (dotted) vs. 2nd Replan



Original plan (left) vs. 1st replan (right)



Practical Issues in Adaptive RT

- R & V upload takes time
- Plan documentation takes time
- QA takes time

- On average, there is a 2.8 fraction delay between the date that the CT is used for replanning and the new plan is used for treatment.

Adaptive radiotherapy is a nature next step for IGRT

- Image-guided radiotherapy
  - Experience from IGRT provides the need ART
  - adaptive radiotherapy is superior to image guidance using rigid registration
  - Better delivered treatment plans
    - Taking advantage of up-to-date patient's anatomy
- Components for ART are available
  - Daily volumetric imaging
  - Deformable image registration
  - IMRT and dose painting