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

Planning CT

During Treatment

CTV is in the air
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

Treatment Strategy – Conventional

A workflow diagram for in-room CT-guided adaptive radiotherapy
**Study Goals**

- Develop a practical procedure for IGRT
- 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**
Mask Setup vs. C2-bone Setup

Retrospectively evaluating Cumulative Dose Distributions Fraction-by-Fraction

Planned vs. Delivered

Cumulative DVH after 33 fractions

Patient #1
Patient #2

BB (skin mark) Setup

Bony Setup (IGRT)

Bone Setup+Replan (ART)

Mask-alignment at the end of treatment
**Patient #2**

**Bone-alignment at the end of treatment**

- **Fx33**
- Dose Volume Histogram

Dotted lines – Original Plan
Solid lines – Adaptive IMRT

**Adaptive Treatment at the end of treatment**

- **Fx33**
- Dose Volume Histogram

Dotted lines – Original Plan
Solid lines – Adaptive IMRT

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**Why parotid dose was lower?**

- Daily Auto-segmentation for adaptive replanning

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**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

- CTVhigh
- CTVlow
- R Parotid
- L Parotid

1st plan 2nd plan

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?

You’ve Got Mail

Original plan (dotted) vs. 1st Replan

1st plan (dotted) vs. 2nd Replan

Dose Volume Histogram
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

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.