Optimization of Internal Margin to Account for Respiratory Motion

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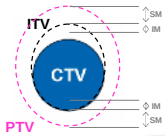
MAYO CLINIC

Introduction

- *Respiratory motion is a source of dosimetric uncertainty*
- *ICRU 62 recommends use of Internal Margin (IM)*
  - *…to compensate for expected physiological movements, variations in shape, size and position of the CTV during therapy…*
  - *Internal Target Volume (ITV) = CTV + IM*
  - *Planning Target Volume (PTV) = ITV + SM*
- *The aim of this study is to find*
  - *Optimum Internal Margin*

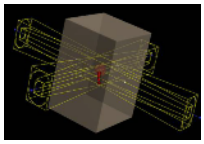


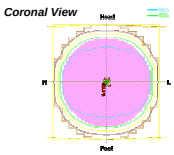
Motion Imaging

- *4DCT or Fluoroscopy*
  - Enables identification of the target motion
  - Ensures only the geometric coverage
    - ✓i.e. where target IS
  - Doesn't provide direct information on the dosimetric effects due to motion
    - ✓i.e. what dose target GETS
- *Determining IM from imaging studies alone* <u>*could be*</u> *overly-conservative*
  - Are smaller margins sufficient?
    - ✓Possible implications regarding dose escalation

Part I – Phantom Study

- *Phantom Simulation*
  - Rectangular body with 3.0cm radius target (TV)
- *Treatment Plans*
  - 4 coplanar, orthogonal fields treat TV
  - *Conformal* in the coronal plane
    - ✓plane of motion
  - Plans with different IM and SM added linearly





Simulation Method

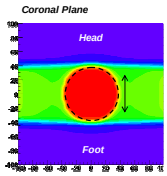
- *Extract dose from the coronal plane at center of the target*
- *Where location of target change due to*
  - Setup Uncertainties through 100 fractions
  - Respiration motion in each fraction

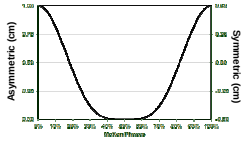
$$A(t) = A_0 \cos^4(\pi\, t/T) - A_0/2$$

$$A(t) = A_0 \cos^4(\pi\, t/T)$$

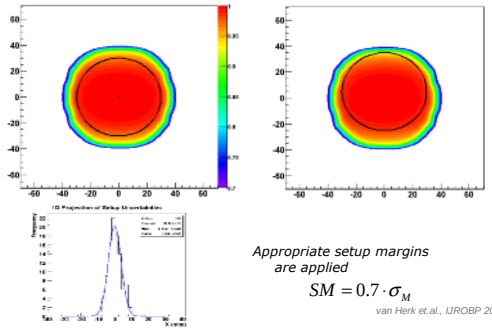
Lujan et.al., MedPhys 99

Coronal Plane





Setup Uncertainties and Respiration

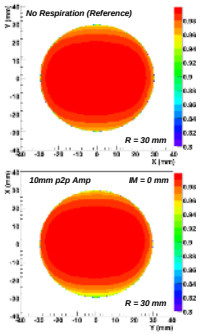


Appropriate setup margins are applied

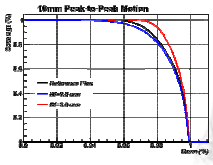
$$SM = 0.7 \cdot \sigma_M$$

van Herk et.al., IJROBP 2000

Comparison of Plans



- *REFERENCE (or STATIC)* Plan
  - No respiration motion (without IM)
  - With setup uncertainties (added SM)
    - ✓ σ_M = *2, 4 and 6 mm*
- *MOTION* Plan
  - With respiration motion (added IM)
    - ✓ 5, 10, 15, 20 mm p2p motion
  - With setup uncertainties (added SM)



Comparison of Plans

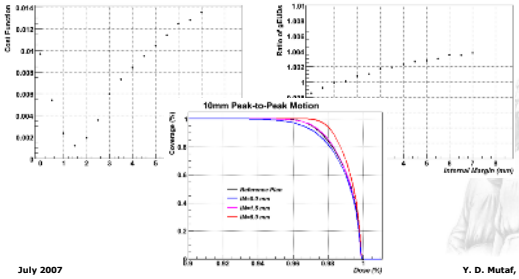
DVH Based Cost Function

$$F = \left[\frac{1}{N} \int_{95\%}^{100\%} \left(D_i^{motion} - D_i^{static} \right)^2 dV \right]^{1/2}$$

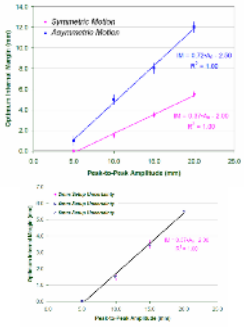
Ratio of gEUDs

$$gEUD = \left(\sum_i v_i D_i^a \right)^{1/a}$$

A. Niemierko Med. Phys. 97

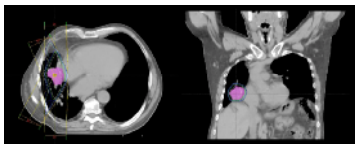


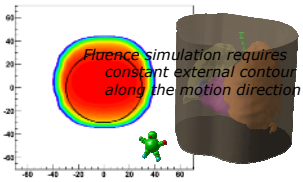
Optimum Internal Margin



- *Optimum dosimetric coverage is obtained with IM smaller than full motion amplitude*
  - Symmetric margins
- *Asymmetric margins*
  - Using the end of exhale images for treatment planning
  - Larger but one sided margins
- *Observed to be independent of the* random *setup uncertainties*
  - Effect of *systematic* uncertainties is not yet investigated

Part II – Patient Study





Fluence simulation requires constant external contour along the motion direction

Patient Cohort

- *12 total patients*
  - 10 lung, 2 pancreas
  - TV range 7 to 210cc
- *Treatment plan characteristics*
  - 3 to 6 beams
    - ✓ All coplanar beams
    - ✓ 6 or 10 MV
  - Conformal in the direction of motion
- *Setup Uncertainties are not simulated*
  - No setup margins (SM)
- *Only 10mm p2p symmetric motion studied*

Note: *Drawings not to scale.*
Targets are indexed in the order of increasing volume.

Comparison of Plans

DVH Based Cost Function

$$F = \left[\frac{1}{N} \int_{95\%}^{100\%} \left(D_i^{motion} - D_i^{static} \right)^2 dV \right]^{1/2}$$

Ratio of gEUDs

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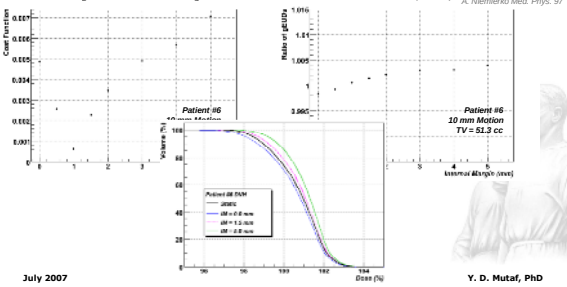
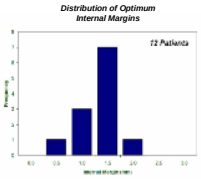
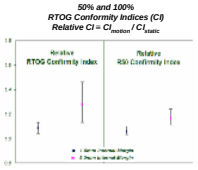


Optimum Internal Margin





Target Coverage (avg of 12 patients)

- Minimum dose is 0.2% colder
  - ✓ TV receiving colder dose is 0.2%
- TV receiving 100% dose (V_{100}) is 0.8% larger
- Relative gEUD is <u>always</u> ≥ 100%

Target Conformity (~ Normal Tissue Sparing)

- 17% less irradiated volume receiving 100% dose
- 10% less irradiated volume receiving 50% dose

Conclusions

- *Optimum Internal Margin (IM) was <u>always</u> smaller than full motion amplitude*
  - Example: ±1.5mm IM for 10mm p2p motion
- *Standard practice of target expansion based on imaging alone (e.g. 4DCT) is overly conservative*
  - "Where Target IS" vs "What Target GETS"
- *As compared to full motion amplitude, optimum internal margin provided*
  - Similar target coverage
  - Improved target conformity

Thank You!