Optimization of Internal Margin to Account for Respiratory Motion

YILDIRIM D. MUTAF, PhD
DEBRA H. BRINKMANN, PhD

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 could be 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

\[ At = A_0 \cos \left(\frac{\pi t}{T}\right) - A_0/2 \]
\[ A(t) = A_0 \cos \left(\frac{\pi t}{T}\right) \]

Lujan et al., MedPhys 99

Setup Uncertainties and Respiration

Appropriate setup margins are applied

\[ SM = 0.7 \sigma_m \]

Comparison of Plans

- REFERENCE (or STATIC) Plan
  - No respiration motion (without IM)
  - With setup uncertainties (added SM)
  - \( M = 2, 4 \text{ and } 6 \text{ mm} \)
- MOTION Plan
  - With respiration motion (added IM)
  - 5, 10, 15, 20 mm p2p motion
  - With setup uncertainties (added SM)

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

Comparison of Plans

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