IGRT Protocol Design and Informed Margins

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Conflict of Interest

- I have no conflict of interest to disclose

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Outline

- Overview and definitions
- Quantification of motion
- Influences on margin selection
- Protocol design
- Marginless planning

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Definitions

- ICRU 50
  - GTV

The GTV is the gross palpable or visible/demonstrable extent and location of malignant growth

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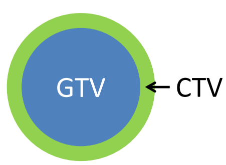
Definitions

- ICRU 50
  - GTV
  - CTV



The CTV is a tissue volume that contains a demonstrable GTV and/or subclinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation.

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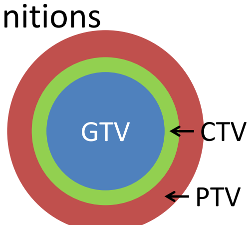
Definitions

- ICRU 50
  - GTV
  - CTV
  - PTV



The PTV is a geometrical concept, defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV.

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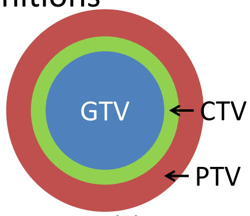
Definitions

- ICRU 50
  - GTV
  - CTV
  - PTV
- ICRT 62
  - Concepts of GTV, CTV, PTV stayed the same
  - PTV components better defined (internal margin, setup margin, etc.)



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What Makes Up A Margin?

- Internal margin compensates for physiologic movements and variations in size, shape, and position of CTV
- Setup margin accounts for uncertainties in patient positioning and alignment
  - Includes positioning, mechanical, and dosimetric uncertainties

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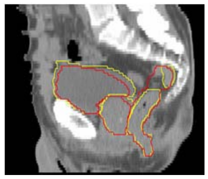
Types of Tissue Motion

- When is the motion happening?
  - Interfractional – day to day variations
    - Difference from time of simulation



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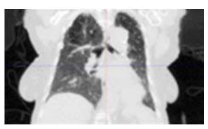
Types of Tissue Motion

- When is the motion happening?
  - Interfractional – day to day variations
    - Difference from time of simulation
  - Intrafractional – variations during treatment
    - Gradual, sudden, periodic



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Quantification of Motion

- Systematic error – an error that will influence all fractions equally
  - An error having non-zero mean
  - Manifests as a shift the cumulative dose distribution relative to the target
- Random error – error caused by factors that vary from one measurement to another
  - Manifests as a blurring of the dose distribution

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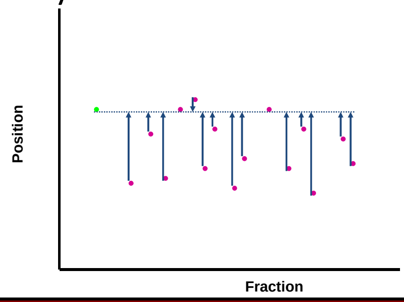
13

Systematic and Random Errors



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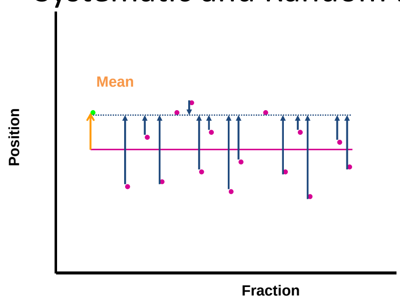
14

Systematic and Random Errors



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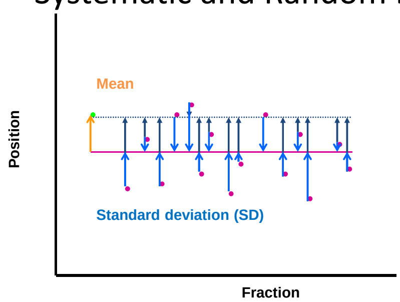
15

Systematic and Random Errors



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Systematic/Random Errors for a Population

	patient 1	Patient 2	patient 3	Patient 4	
Day 1	2	4	1	3	
Day 2	1	-2	-1	-3	
day 3	1	2	2	-2	
day 4	1	0	2	1	
					Mean = M = 0.75
Mean	1.25	1	1	-0.25	SD = Σ = 0.68
SD	0.50	2.58	1.41	2.75	RMS = σ = 2.03

Fig 1. Estimation of the SD of random and systematic errors based on measurements in a population of patients. The numbers in this table could represent, for instance, a shift of the patient in millimeters in the left-right direction determined using electronic portal imaging. For each patient, the mean and SD of measurements of several fractions is determined. Different combinations of these values give an estimate of the errors for a population of patients.

van Herk, M. (2004). "Errors and margins in radiotherapy." Semin Radiat Oncol **14**(1): 52-64.

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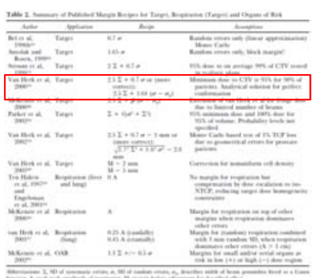
Margin Recipes



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Influences on Margin

- Systematic/random error quantification paired with established margin recipes can give a good estimate of appropriate margin
- Errors dependent on <u>many</u> factors

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Disease Site

- Most obvious and arguably most important
- Different disease sites move differently
- Lung – large, semi-regular cyclical tumor motion[1]
- Prostate – bladder/rectal filling and large, sudden intrafractional motion[2]
- Spine SBRT – mostly rigid, close proximity to critical structures

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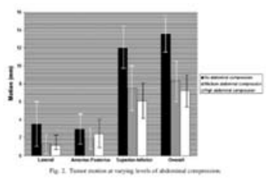
[1]Keall et al (2006). "The management of respiratory motion in radiation oncology report of AAPM Task Group 76." Med Phys **33**(10): 3874-3900.
[2]Kupelian et al (2007). "Multi-institutional clinical experience with the Calypso System in localization and continuous, real-time monitoring of the prostate gland during external radiotherapy." Int J Radiat Oncol Biol Phys **67**(4): 1088-1098.

Immobilization/Motion Management

- Closely linked to disease site
- Motion can be reduced by
  - compression[1], breath hold, gating,[2] etc.



[1]Heinzerling et al (2008). "Four-dimensional computed tomography scan analysis of tumor and organ motion at varying levels of abdominal compression during stereotactic treatment of lung and liver." Int J Radiat Oncol Biol Phys **70**(5): 1571-1578.
[2]Keall et al (2006). "The management of respiratory motion in radiation oncology report of AAPM Task Group 76." Med Phys **33**(10): 3874-3900.

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Type of Treatment/Dose Distribution

- "Geometrical miss" can be mitigated by a forgiving dose falloff
- Dosimetric effects of dose falloff not as severe for 3D conformal vs. IMRT/SBRT
- Some margin formulas take this into account with beam penumbra parameter

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Length of Treatment

- In general, the longer the treatment, the greater chance of something going wrong
- Prostate provides a good example

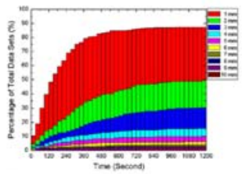

Fig. 10. Percentage of data sets for the prostate target as a function of sample interval and movement threshold.

Xie, et al (2008). "Intrafractional motion of the prostate during hypofractionated radiotherapy." Int J Radiat Oncol Biol Phys **72**(1): 236-246.

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Correction Strategies

- What is being used and how often?
- Image Guidance
  - Portal imaging, orthogonal kV, CBCT
  - Each imaging modality has inherent accuracy
  - Imaging of surrogate vs. target
- Couch – translational vs. full 6D rotational strategies

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Correction Strategies – Prostate Example

	LR (mm)	AP (mm)	SI (mm)
Setup to skin marks	8.2	10.2	12.5
Initial setup to prostate transponders	1.8	5.8	7.1
Interbeam adjustments to transponders	1.4	2.3	1.8

Litzenberg et al (2006). "Influence of intrafraction motion on margins for prostate radiotherapy." Int J Radiat Oncol Biol Phys **65**(2): 548-553.

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Protocol Design

- Each treatment has become increasingly individualized
- Each clinic has own treatment protocols
- Cannot give a prescriptive “one size fits all” recommendation
- Start by setting standards for most common treatments
  - Make this a collaborative effort – involve the Docs!

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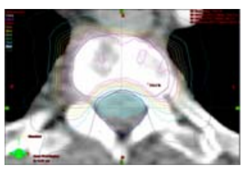
Protocol Design - Example

- Spine SBRT
  - Generally high dose (18 Gy x 1 fx)
  - High dose falloff
  - Proximity to cord
  - Intent of treatment
  - Well defined/ visualized



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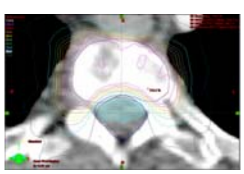
Protocol Design - Example

- CBCT – correct for rotational errors
  - Resolution alone yields uncertainty of ~1.5mm[1]
- Isocentric alignment ~1mm
- Interfractional motion
  - Mitigate with repeat imaging
  - ~1mm
- Total uncertainty ~2mm
- Good candidate for asymmetric margin
  - Match to cord



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[1]Schell et al (1995). "Stereotactic radiosurgery." AAPM Report 54.

Marginless Planning

- It is possible to do away with PTV margins altogether
- Optimize on the CTV directly
  - Maximize the probability of CTV coverage in the face of various uncertainties

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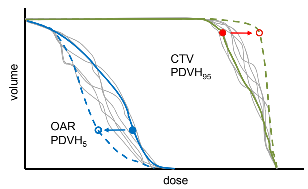
Coverage optimized planning

Coverage optimized planning is based on percentile DVHs (PDVHs):



PDVH optimization criteria:	Pr [CTV D_{98} > TD] ≥ 95%
	Pr [OAR D_{20} < OD] ≥ 95%

Slide courtesy J. James Gordon

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Gordon et al (2010). "Coverage optimized planning: Probabilistic treatment planning based on dose coverage histogram criteria." Medical Physics **37**(2): 550-563.

Xu et al (2014). "Coverage-based treatment planning to accommodate deformable organ variations in prostate cancer treatment." Med Phys **41**(10): 101705.

Conclusions

- Margins are complicated
- Set protocols for your most common procedures
  - Then don't treat them as absolutes
- Must be catered to individual treatment at hand

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Thank You!

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