Treatment Planning Considerations for Adaptive Radiotherapy

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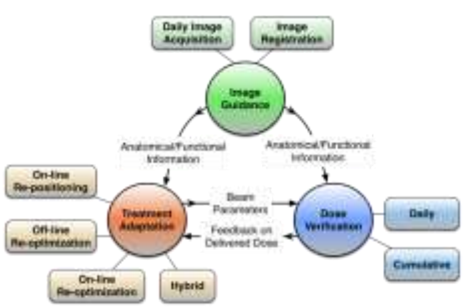
Key Elements Of ART



Wu et al, *Cancer Journal* 17:182-189, 2011

Tx Planning Considerations for ART

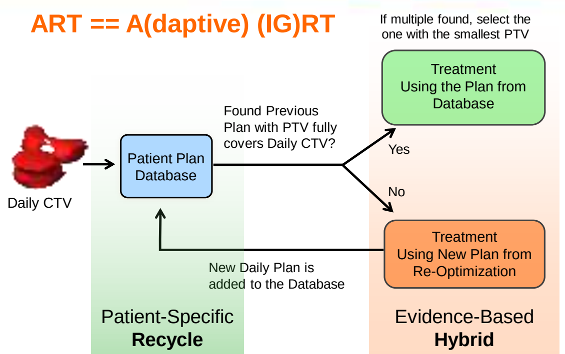
- Complicated & Resource-Intensive → **When to Adapt**
- Goal of Adaptation not Well Defined → **How to Adapt**
- Current QA Protocol Time Intensive → **How to Verify**

When to Adapt?

Re-Positioning		Re-Planning
Highly Efficient	**Efficient & Effective**	Inefficient
Less Effective		Very Effective

- use when sufficient (Re-Positioning)
- use when necessary (Re-Planning)

ART == A(daptive) (IG)RT



Li et al, *Physics in Medicine and Biology* 56:1243-1258, 2011

Benefits: Target (CTV) Coverage

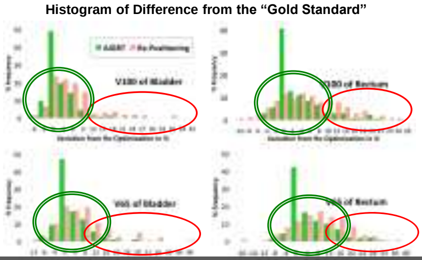
Ranges and Means of D99 (Minimal Dose to 99% CTV)

ART can substantially improve target coverage.

Li et al, *Phys Med Biol. 2011 Mar 7;56(5):1243-58.*

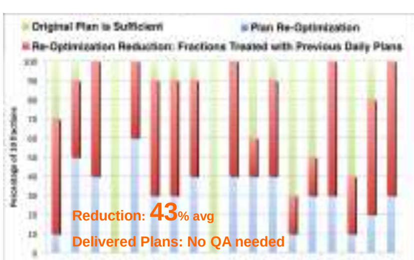
Results: OAR Sparing

Histogram of Difference from the “Gold Standard”



Better Controlled OAR Irradiation than Re-Positioning

Benefits: Efficiency Improvement



Substantially reduced re-optimization necessity

½ Re-Optimizations, Same Quality

Improved
OAR Sparing
Compared to Re-Positioning

Uncompromised
daily CTV Coverage
(D99 > 98%)

Reduced
Re-Optimization Frequency
by 43%

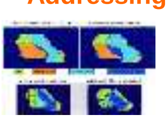
From Challenges to Tools

When to Adapt → Daily Evidence-Based Decision Making

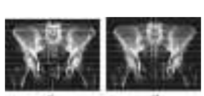
How to Adapt → Motion Management

How to Verify → Online Quality Assurance

Addressing Inter-fractional Change



Fluence-map Deformation
Based on BEV
Mohan et al. 2005



Direct-Aperture-Def.
Based on BEV
Feng et al. 2006

LP Fluence Opt.
Based on Sturctures.
Wu et al. 2008

MLC Position Shift
Based on BEV
Court & Dong et al. 2005

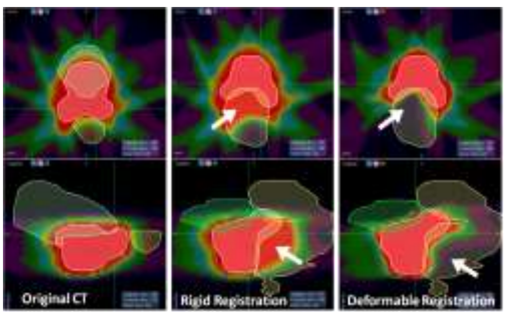
Aperture morphing
Based on BEV
Ahunbay et al. 2008

Knowledge-Guided Plan Adaptation

- **Step 1. Deformable registration of Daily and Planning CT images**
  - **Warping planned dose to changed anatomy**
  - **Known *Goal* dose**
- **Step 2. Auto-optimization**
  - **Known optimization parameter settings**
- **Step 3. Knowledge based plan quality QA**
  - **known plan quality parameters**

Thongphiew et al, *Med Phys* 36:1651-1662, 2008
Li et al, *Med Phys* 40, 111711, 2013

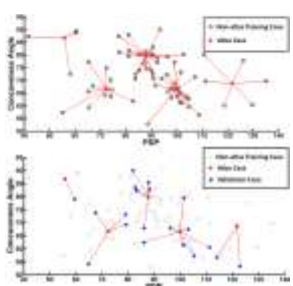
Step 1. Deform the Original Dose for New Anatomy



Li et al, *Med Phys* 40, 111711, 2013

Dose Atlas Guiding Optimization

- Features of all cases covered by only 5 atlas
- New anatomy matched to nearest atlas
- Deformable Registration used to apply atlas dose to new anatomy
- Goal dose guides optimization



Sheng and Li et al, Phys. Med. Biol. ***60*** *(2015) 7277*

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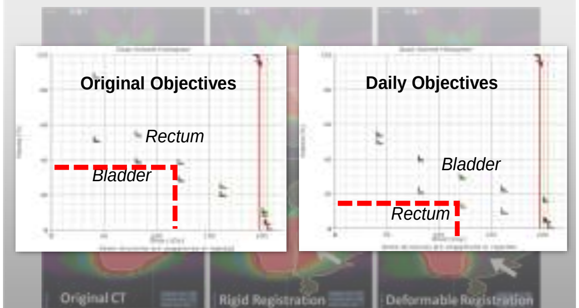
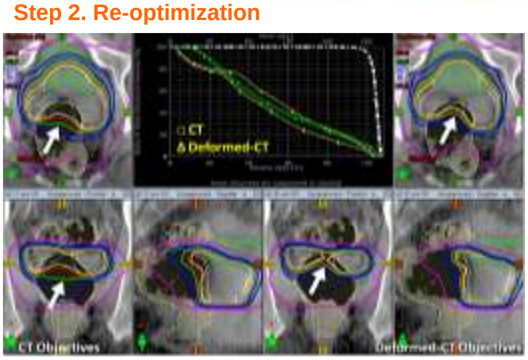
Thongphiew et al, *Med Phys* 36:1651-1662, 2008

Step 2. Optimization Objective from Daily Imaging



Li et al, *Med Phys* 40, 111711, 2013

Step 2. Re-optimization



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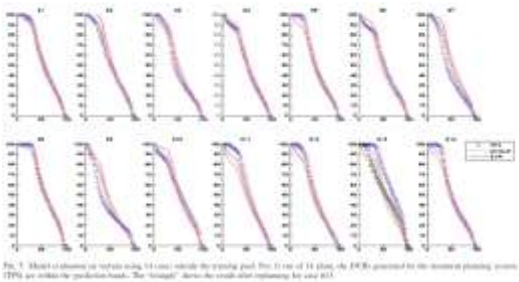
Step 3. Plan Quality QA

Planned vs. Modeled

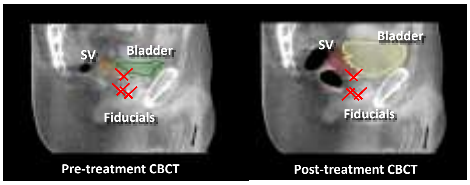


Zhu et al, *Med Phys* 38:719-726, 2011

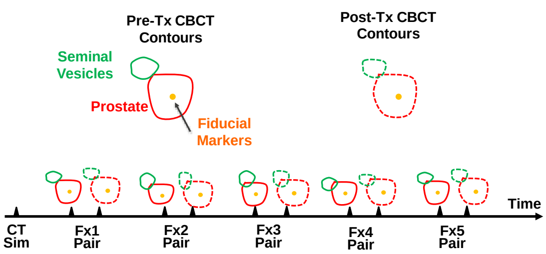
Addressing Intra-fractional Change

- Online Adaptation = 0 Margin?
  - Inter-fractional motion can be managed with plan adaptation
  - Intra-fractional motion requires tracking or additional margin
- SV motion as example
  - Prostate tracking: simple with fiducial markers
  - SV tracking: difficult & requires margin

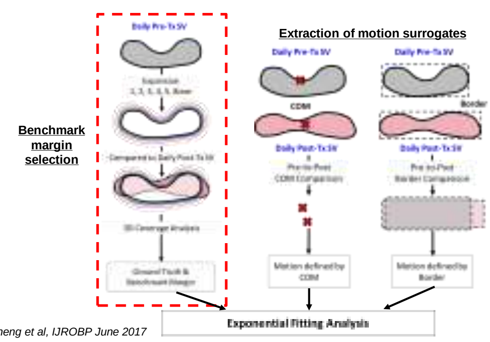
Inter-fractional SV Motion



Quantifying Intra-fractional Motion



Motion Definition



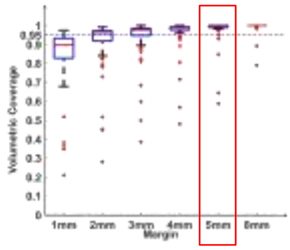
Sheng et al, IJROBP June 2017

Margin: 5 mm for SV Alone

Isotropic margin (mm)	95% post-tx SV coverage (% fractions)
1	9
2	53
3	73
4	86
5	95
8	97

5mm: selected as minimal margin for sufficient coverage

SV volumetric coverage distribution for each isotropic margin



Sheng et al, IJROBP June 2017

Margin: Surrogate Underestimates

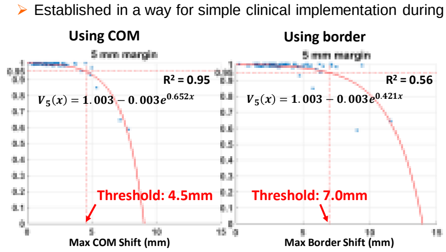
- Margin determined from surrogates
  - Using popular Van Herk's recipe
  - Based on motion estimated from COM and Border

Van Herk Margin			
	LR	AP	SI
Center of Mass	0 mm	0.5 mm	0.8 mm
Border	1.2 mm	3.9 mm	2.5 mm

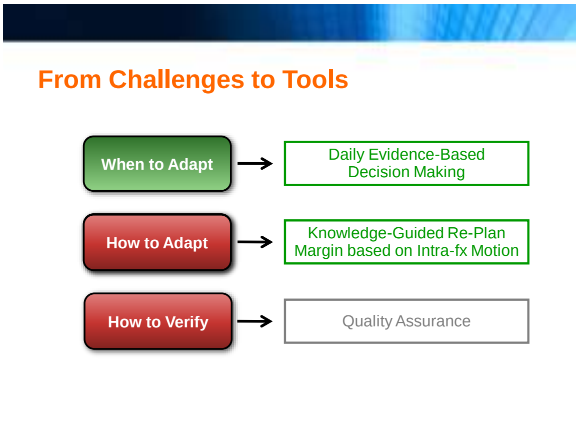
Sheng et al, IJROBP June 2017

Predicting SV Coverage via IGRT

- SV Coverage Prediction via Regression
  - Based on fractional coverage data
  - Established in a way for simple clinical implementation during IGRT



Sheng et al, IJROBP June 2017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When to Adapt
Daily Evidence-Based Decision Making
How to Adapt
Knowledge-Guided Re-Plan Margin based on Intra-fx Motion
How to Verify
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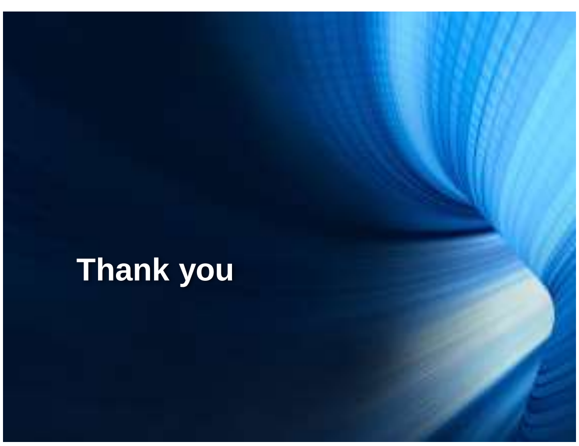
How to Verify
Dr. Dan Low's Presentation


Thank you