An updates on ART for
prostate, pancreas and breast

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Medical College of Wisconsin

TH-E-137, AAPM Edu Course, Aug. 8, 2013

Acknowledgement

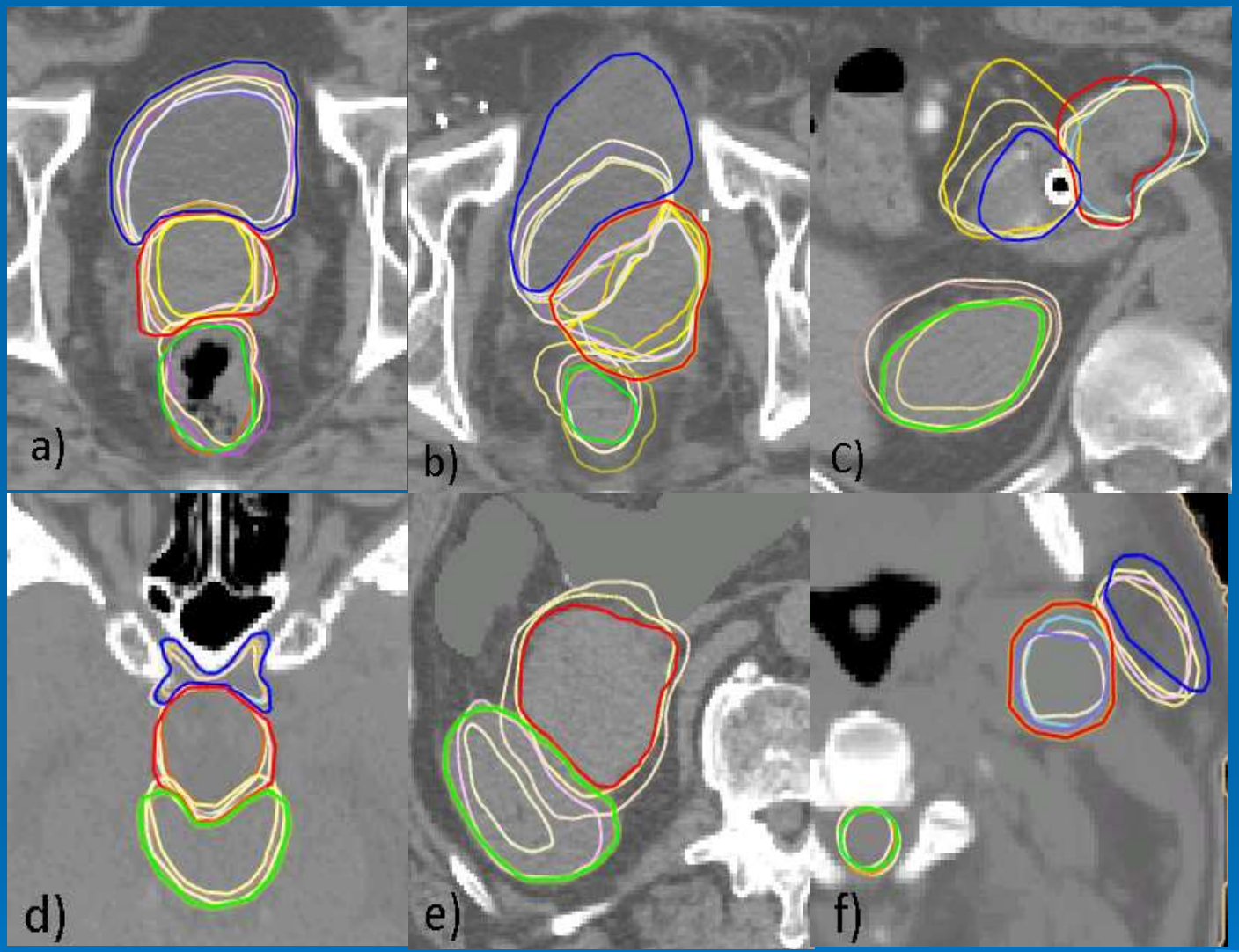
- Ergun Ahunbay, Ph.D
- Guangpei Chen, Ph.D
- Feng Liu, Ph.D
- Natalya Morrow, Ph.D
- Victor Chen, Ph.D
- Cheng Peng, Ph.D
- Andrew Godley, Ph.D
- Colleen Lawton, MD
- Dian Wang, MD
- Beth Erickson, MD
- Chris Schultz, MD
- Julia White, MD
- J. Frank Wilson, MD
- Chengliang Yang, MD

Funding Supports: MCW, Fotsch, Siemens, Prowess

Learning Objectives

- Understanding rationale, indications and promise of ART
- Review of imaging, planning, and delivery technologies for ART
- Recent technology developments
- Clinical implementation, workflow, QA, cautions and initial clinical experience for using ART at several tumor sites.

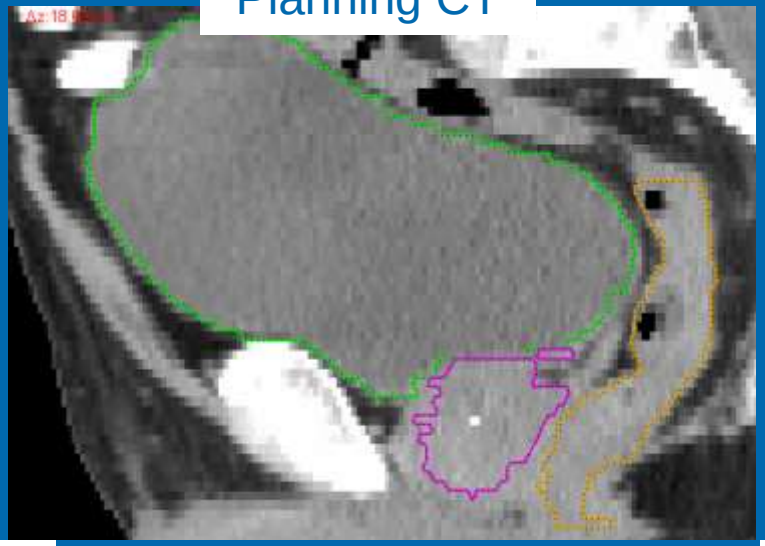
In-room imaging



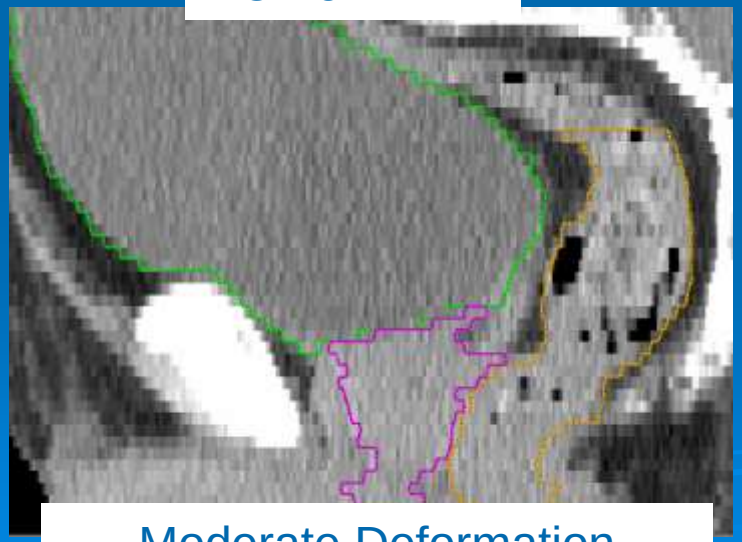
Daily contours overlaid with planning contours (target in red). (a) prostate, (b) prostate (c) pancreas, (d) craniopharyngioma, (e) adrenal carcinoma, (f) head-and-neck cancer. The planning CTs were registered with daily CTs by aligning the center of mass of the targets.

Prostate case (2 fractions)

Planning CT



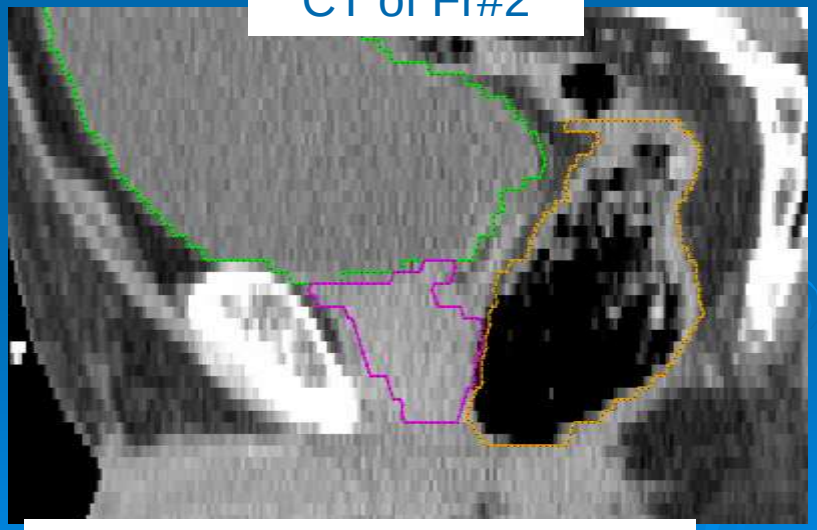
CT of Fr#1



Moderate Deformation

Overlap: 85%

CT of Fr#2



Large Deformation

Overlap: 74%

Interfraction variations (setup errors, anatomy changes) is a major issue affecting RT

Seems changes are being found wherever and whenever one looks

IGRT
- *reposition the patient without modifying plan*
- addresses setup error and organ translational variation but not organ deformation and rotation

Adaptive Replanning is needed !

On-line vs. off-line ART

Off-line ART

- replan based on previous fractions and deliver to subsequent fractiions
- *gradual/systematic changes*
- *e.g., **H&N, lung, breast, cervix***

On-line ART

replan near real-time prior to a fraction and deliver to the fraction

unpredictable/random changes

*e.g., **prostate, pancreas, cervix, breast***

Challenges for online ART

- Imaging quality (e.g., CBCT)
- Accuracy and efficiency of auto-segmentation
- replanning time
- QA
- Intrafractional changes
- Accuracy of deformable image registration

Example of online ART techniques

- Replan by deforming fluence map based on anatomy of the day (Mohan, MDACC)
- MLC segment morphing (Yu, Uni MD),
- Segment morphing and weight optimization (Li, Ahunbay, MCW)
- Adaptation using plan library created from pre-simulated volume and anatomy changes (several groups, Wu, Duke, ….)
- GPU-powered image registration, dose calculation and re-optimization (Jiang, UCSD)
- Auto-segmentation and auto-plan tools (Li, Zhang, MDACC)
- …..

MCW Online ART

Image Acquisition via CT-on-Rails

↓

Contour generation (auto segmentation with manual editing) 2-5 min

↓

Segment Aperture Morphing (**SAM**) & Segment Weight Optimization (**SWO**) 2 min

↓

Dose/DVH evaluation and comparison 1 min

↓

ART plan transferring & QA verification with software 2 min

↓

Delivery and documentation

8-12 min for prostate

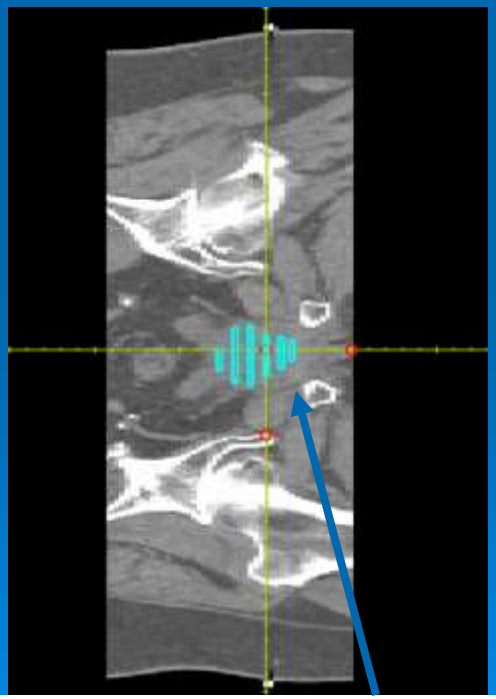
Rapid contour delineation/modification

Software:

- auto segmentation
- drag and drop planning contours
- interpolate contours for skipped images

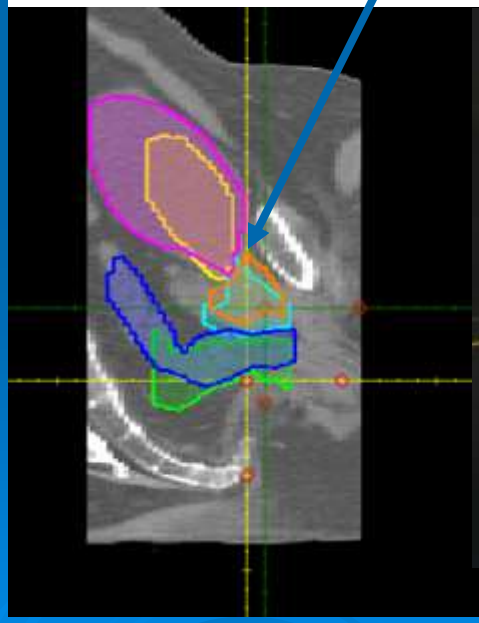
Hardware:

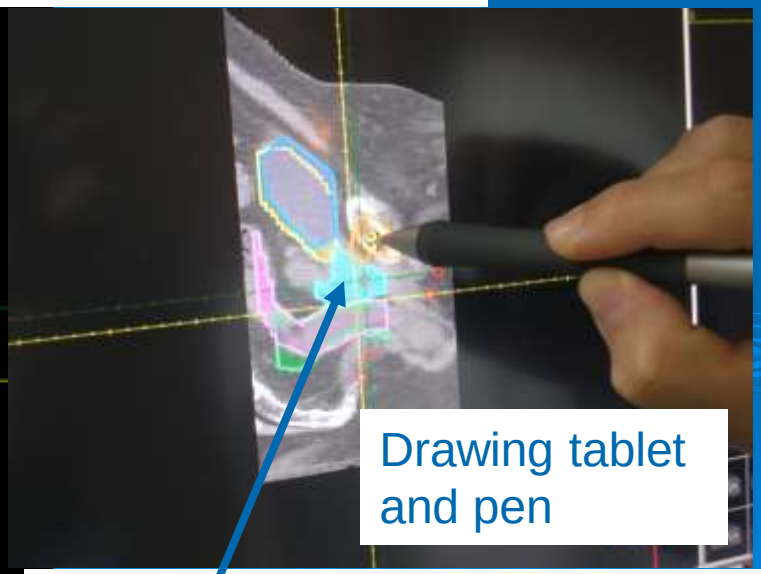
user-friendly interactive Grip pen display (Cintiq 21UX, Wacom).



Decimating/Interpolating slices

Dropping contours from planning CT



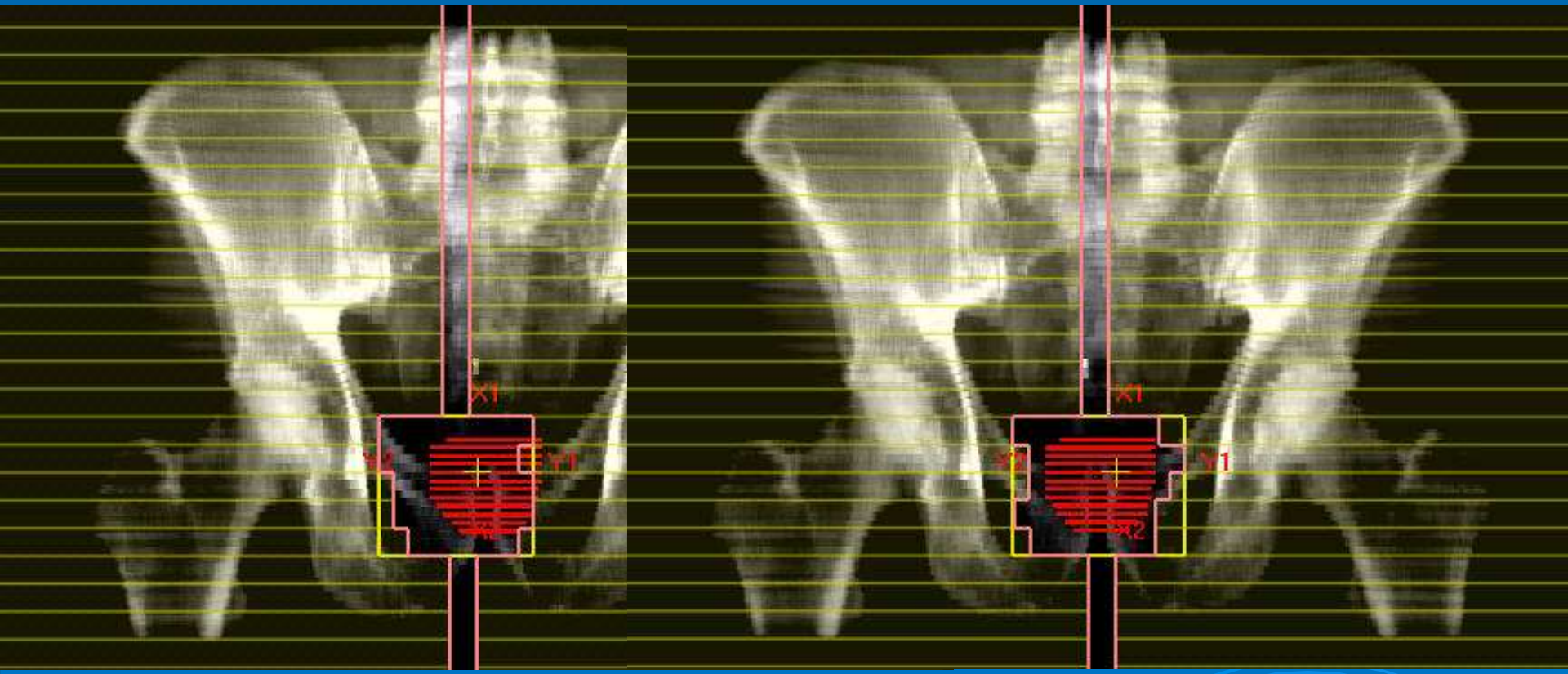


Drawing tablet and pen

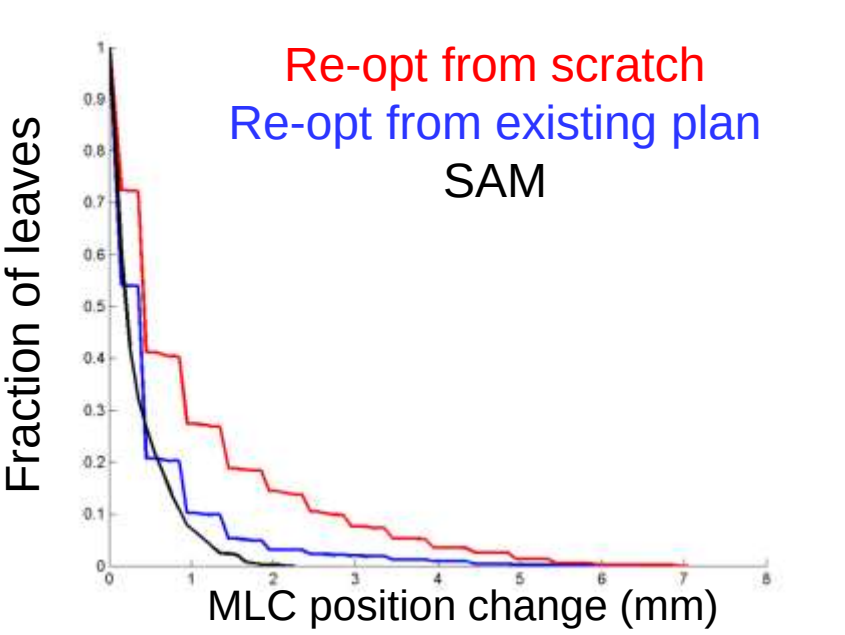
Moving in Sagittal/Coronal view

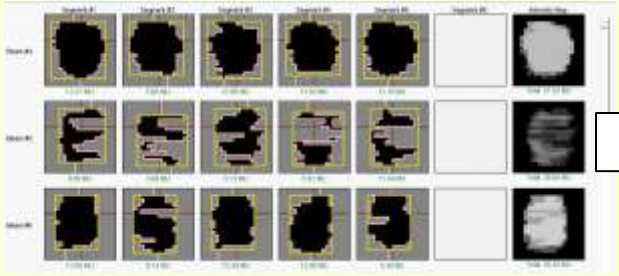
Fast plan modification:

Segment Aperture Morphing

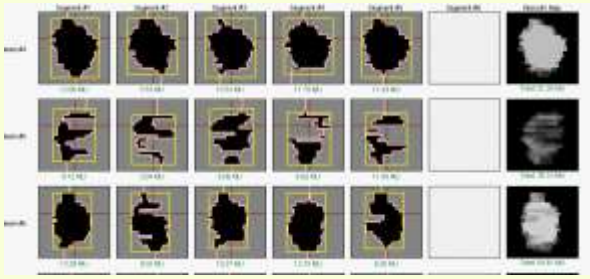


How to perform pre-Tx QA for online ART Plans?

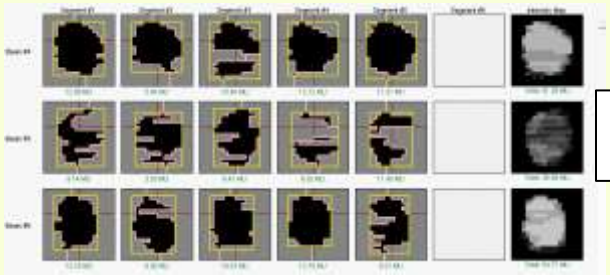




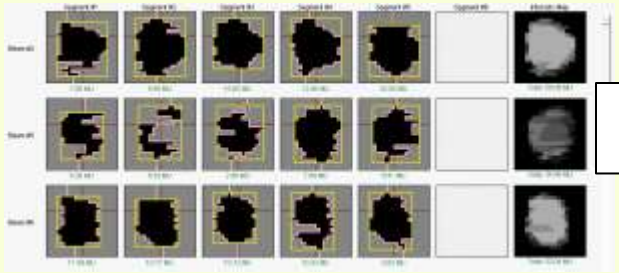
Original plan



SAM



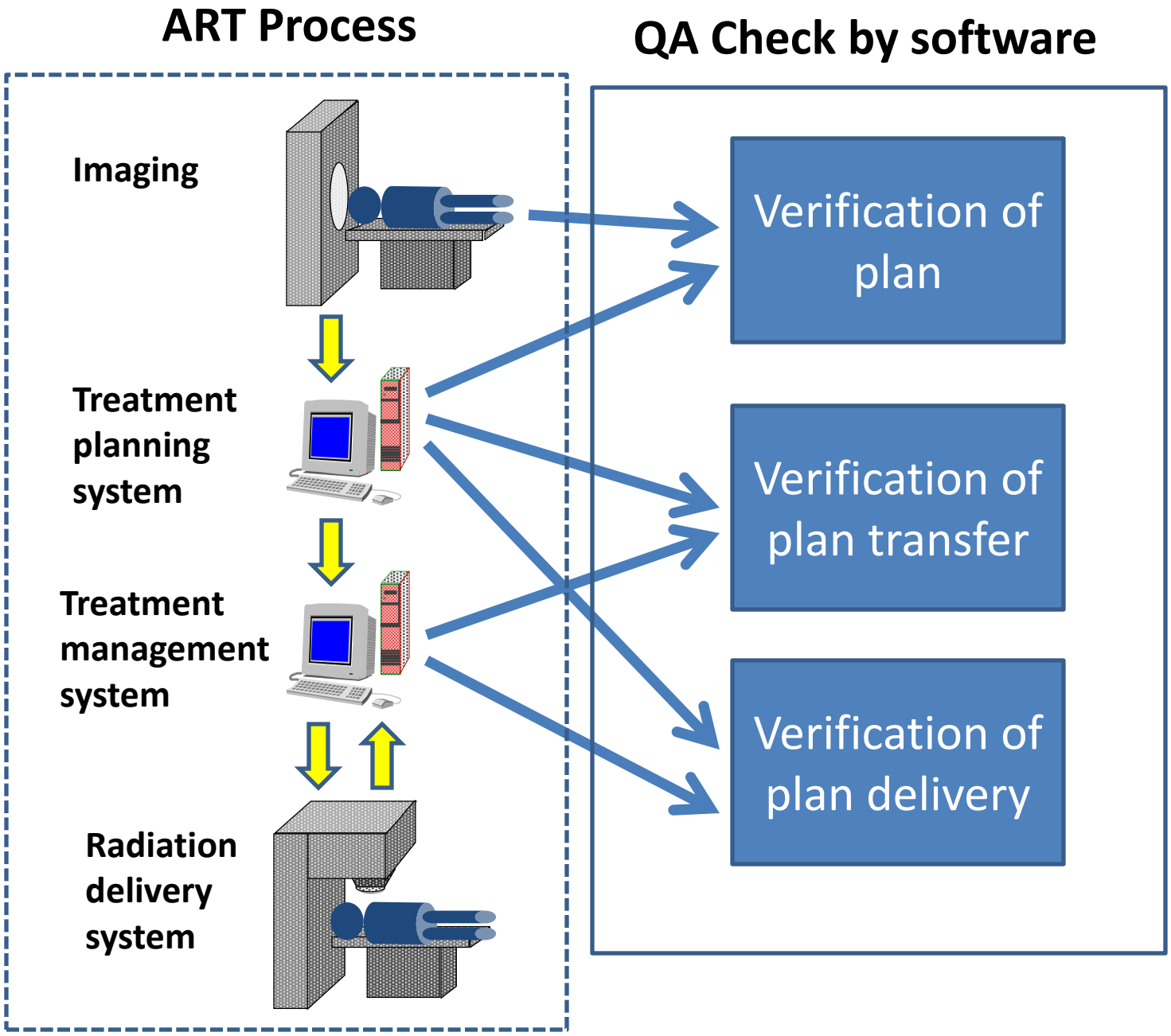
Re-opt from existing plan



Re-opt from scratch

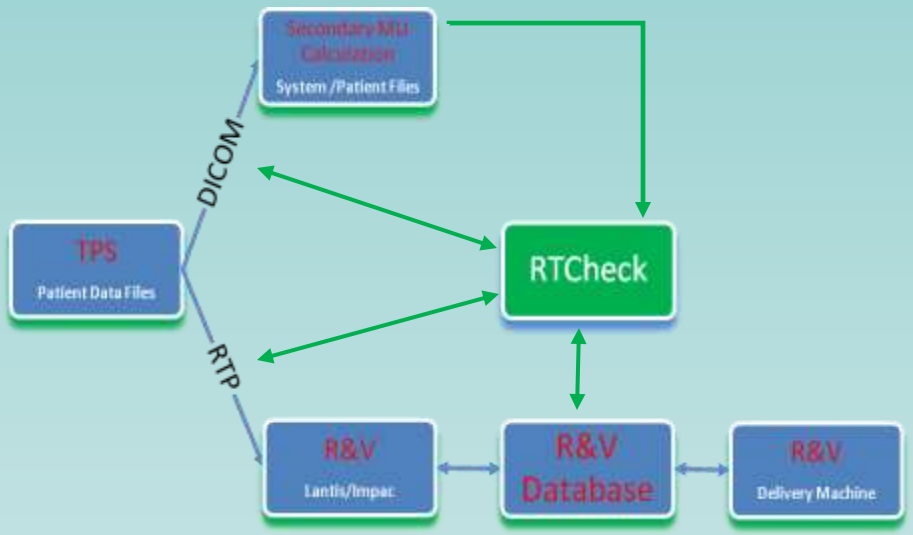
96% of leaf changes < 1mm for SAM plan)

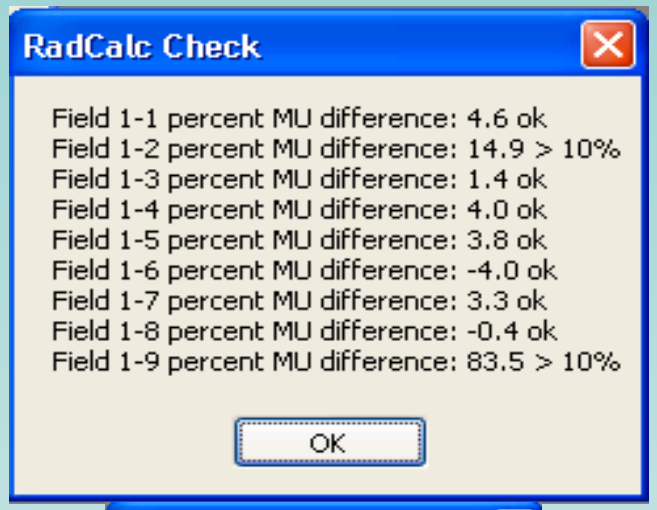
Pre-Tx QA with software may be adequate, as long as original plan is fully QA'ed.

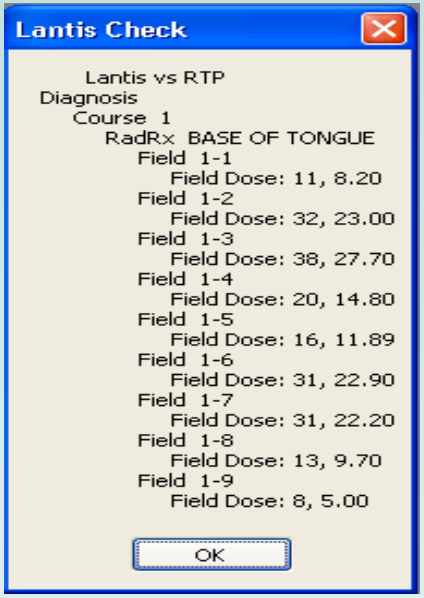

ART Process
QA Check by software
Imaging
Treatment planning system
Treatment management system
Radiation delivery system
Verification of plan
Verification of plan transfer
Verification of plan delivery

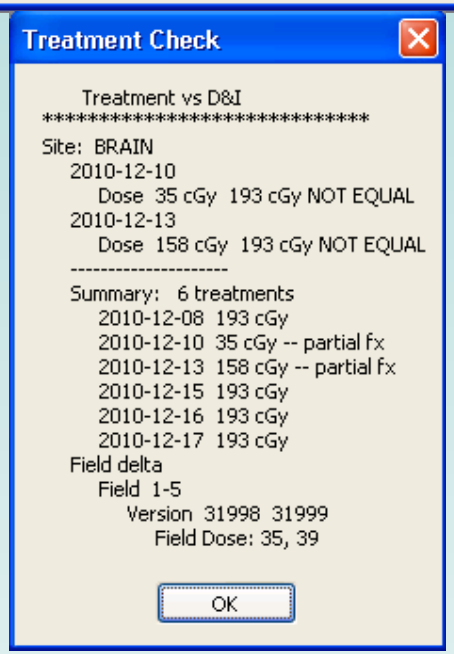
Software tools for QA prior and after delivery:

verifying MU#, plan data transferring and actual delivery



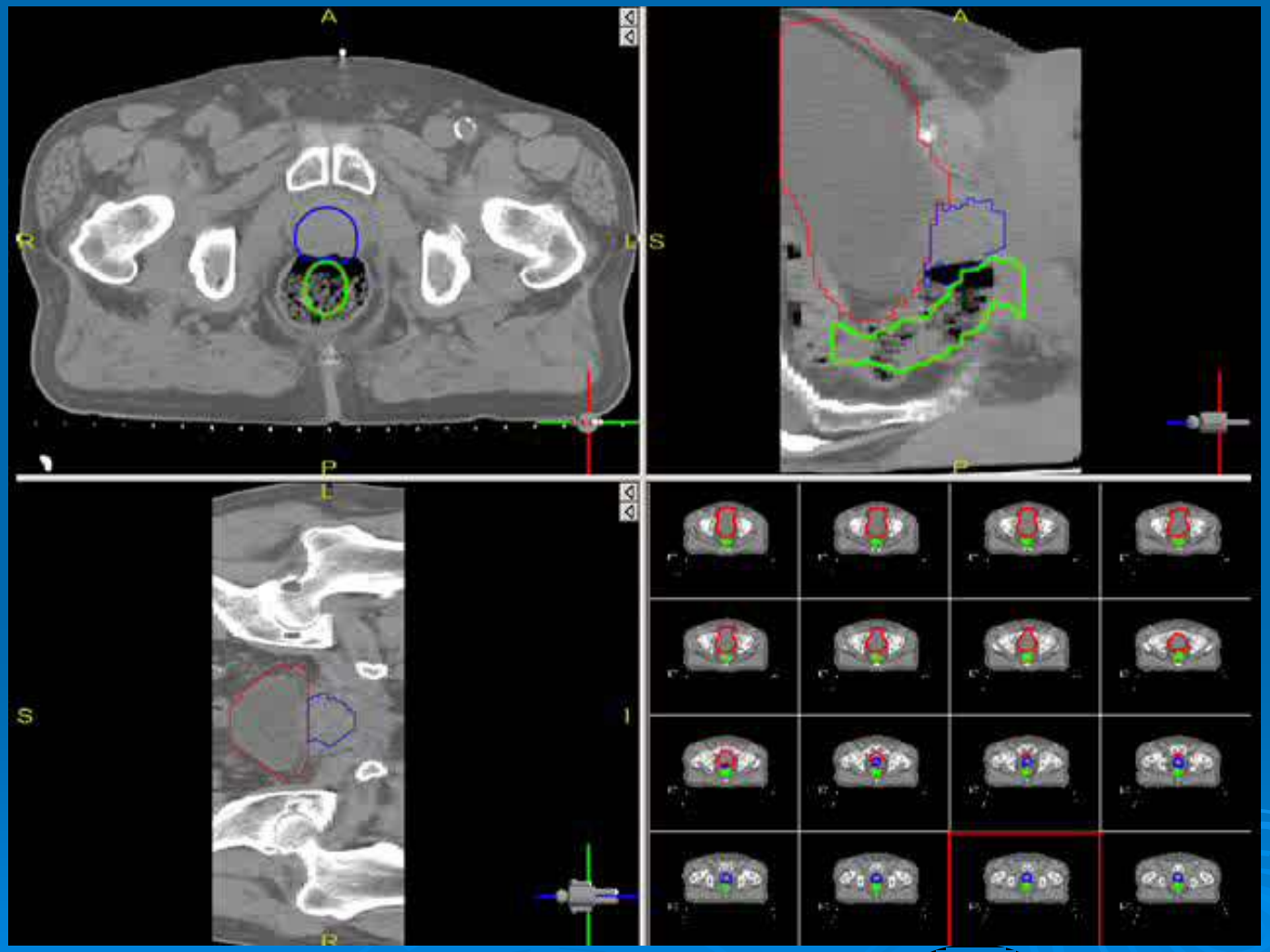






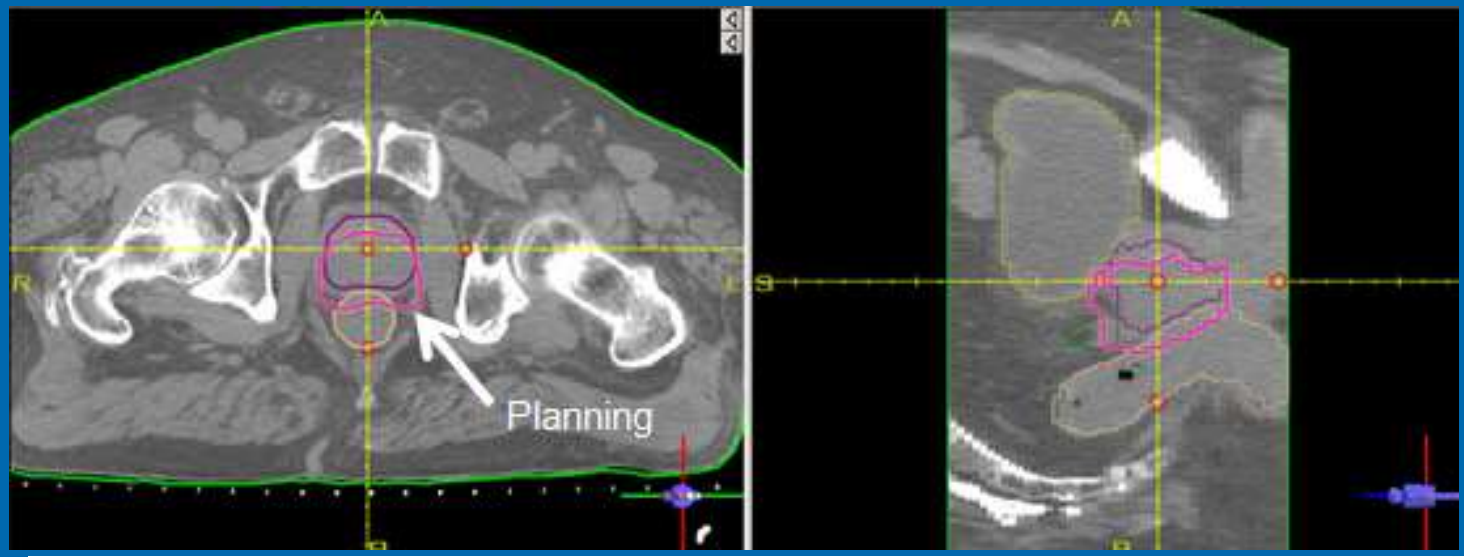
Online ART for prostate

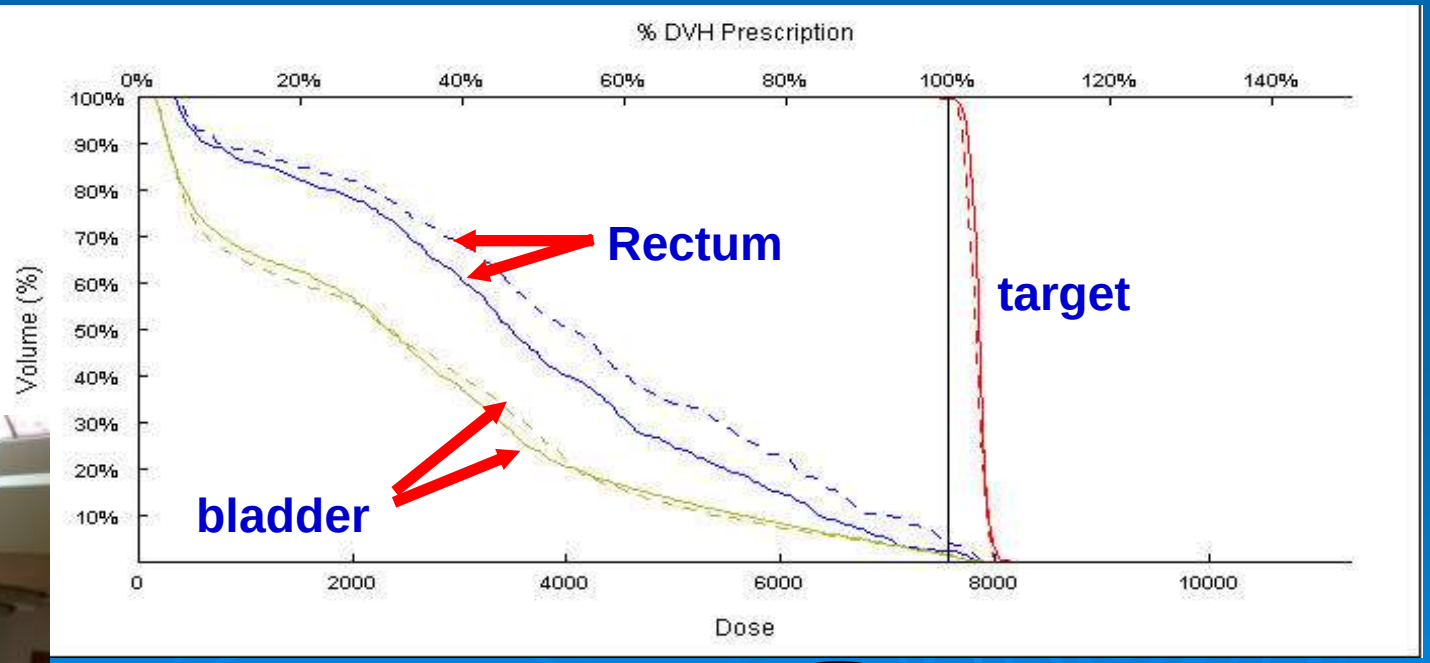
Prostate: unpredictable inter-fraction change



On-line ART

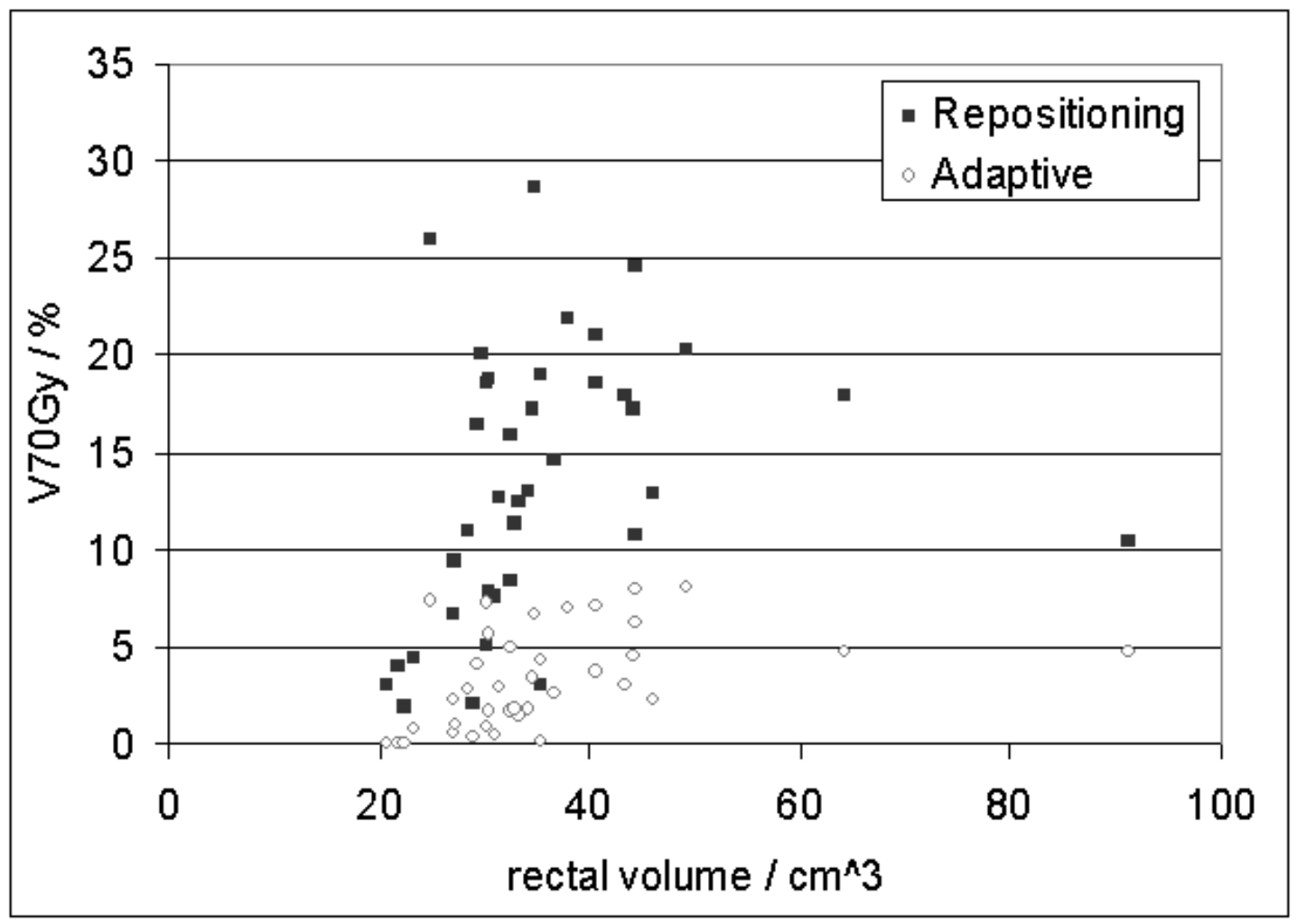
Prostate



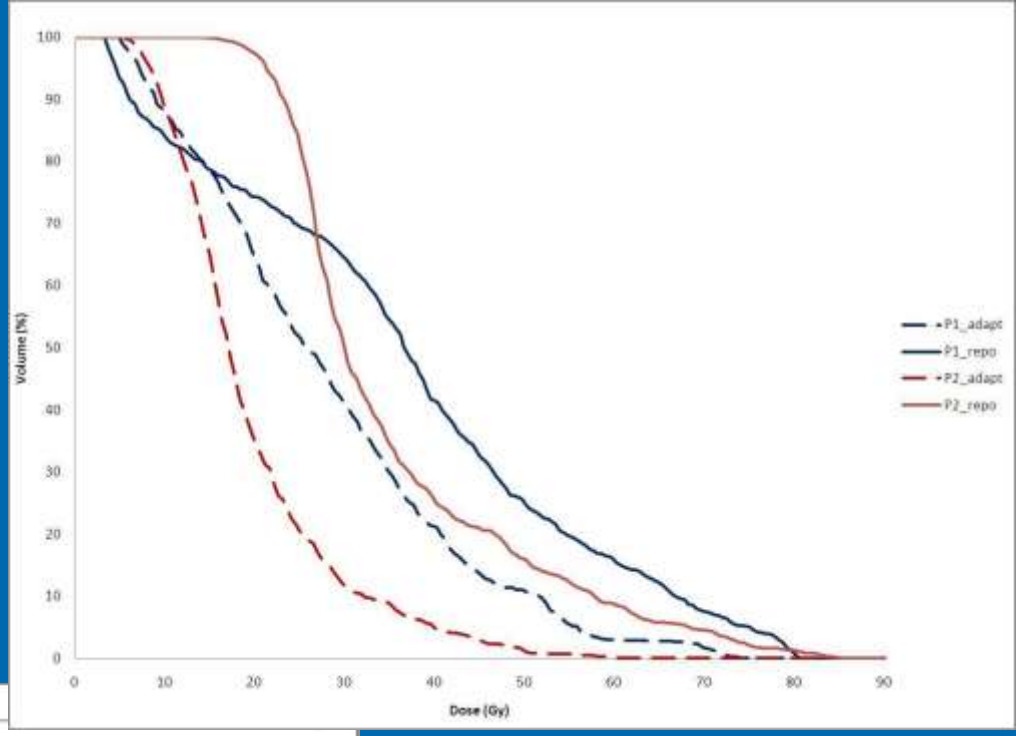


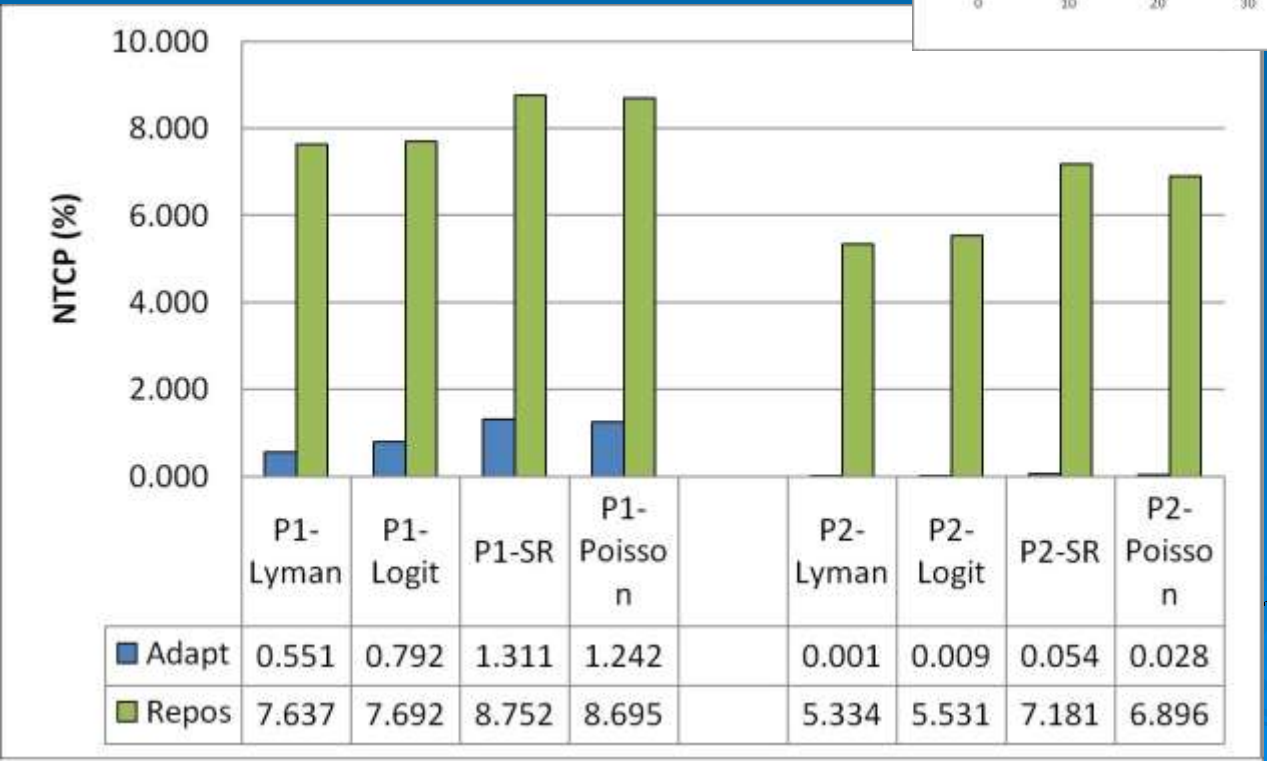
Dash: IGRT repositioning. Solid: online ART

Rectum


35
30
25
20
15
10
5
0
V70Gy / %
0
20
40
60
80
100
rectal volume / cm^3
Repositioning
Adaptive

Projected reduction in rectal bleeding





	P1-Lyman	P1-Logit	P1-SR	P1-Poisson		P2-Lyman	P2-Logit	P2-SR	P2-Poisson
Adapt	0.551	0.792	1.311	1.242		0.001	0.009	0.054	0.028
Repos	7.637	7.692	8.752	8.695		5.334	5.531	7.181	6.896

Initial Clinical Experience with Prostate

Online ART has been used on 12 prostate cancer cases and one bladder cancer case so far.

Online replanning, eliminating the need to shift the patient, can be performed within the similar or slightly longer time frame required for the current IGRT repositioning and fits into the routine clinical workflow.

Practical Radiation Oncology (2013) xx, xxx–xxx

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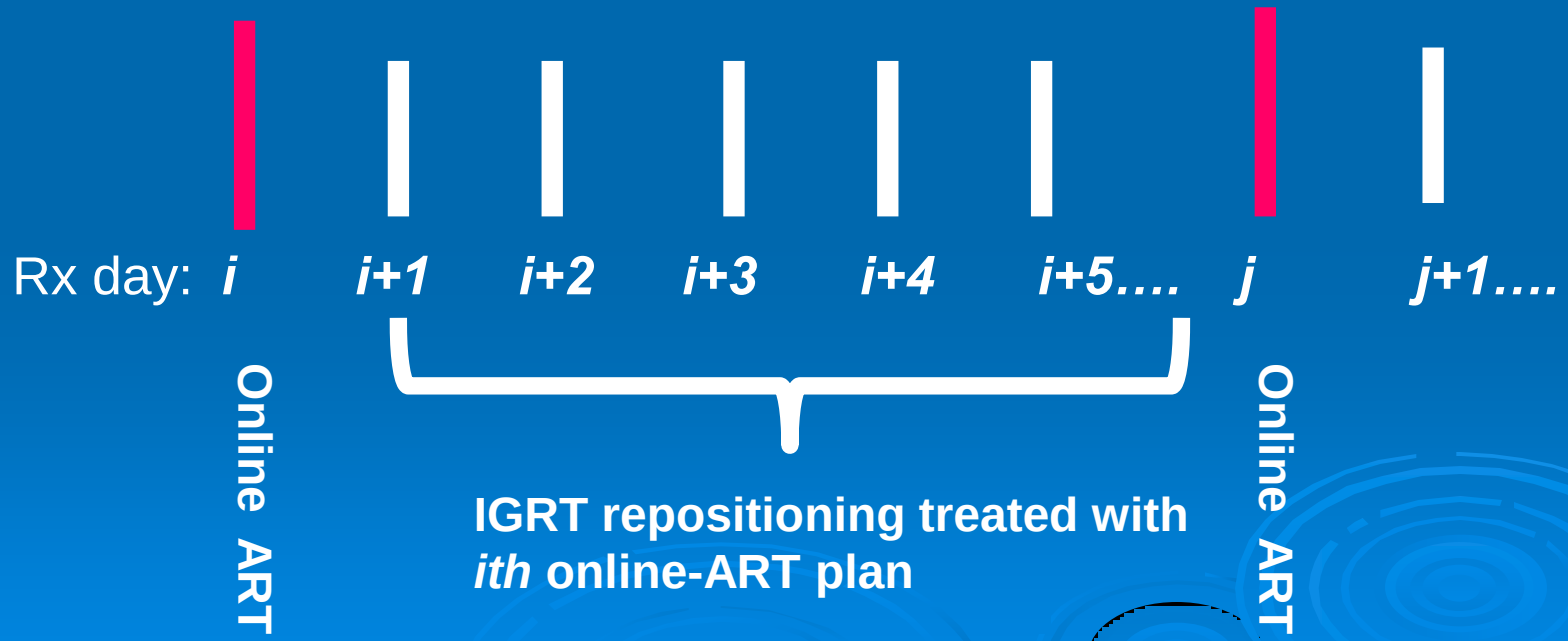
Original Report

Combined online and offline adaptive radiation therapy: a dosimetric feasibility study

Chengliang Yang MD [a,b], Feng Liu PhD [a], Ergun Ahunbay PhD [a], Yu-Wen Chang PhD [a], Colleen Lawton MD [a], Christopher Schultz MD [a], Dian Wang MD [a], Selim Firat MD [a], Beth Erickson MD [a], X. Allen Li PhD [a,*]

Hybrid ART: online ART + IGRT



International Journal of Radiation Oncology biology • physics

www.redjournal.org

Clinical Investigation: Genitourinary Cancer

A Fully Automated Method for CT-on-Rails-Guided Online Adaptive Planning for Prostate Cancer Intensity Modulated Radiation Therapy

Xiaoqiang Li, PhD,* Enzhuo M. Quan, PhD,* Yupeng Li, MS,* Xiaoning Pan, PhD,‡ Yin Zhou, PhD,† Xiaochun Wang, PhD,* Weiliang Du, PhD,† Rajat J. Kudchadker, PhD,* Jennifer L. Johnson, MS,* Deborah A. Kuban, MD,† Andrew K. Lee, MD,† and Xiaodong Zhang, PhD*

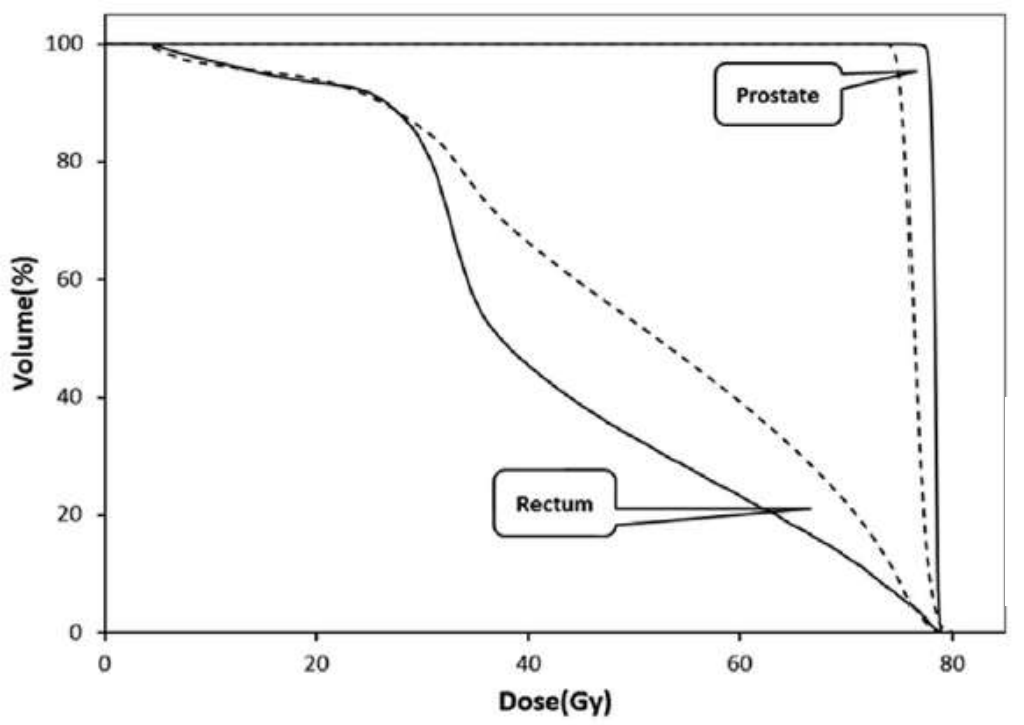
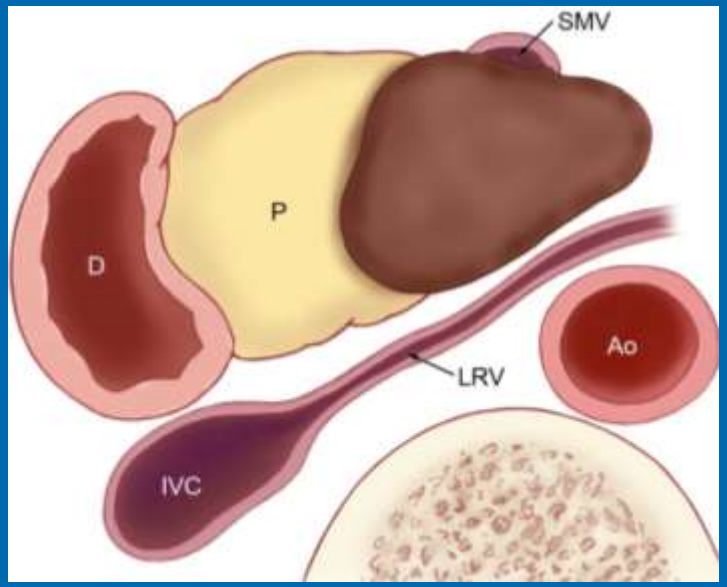
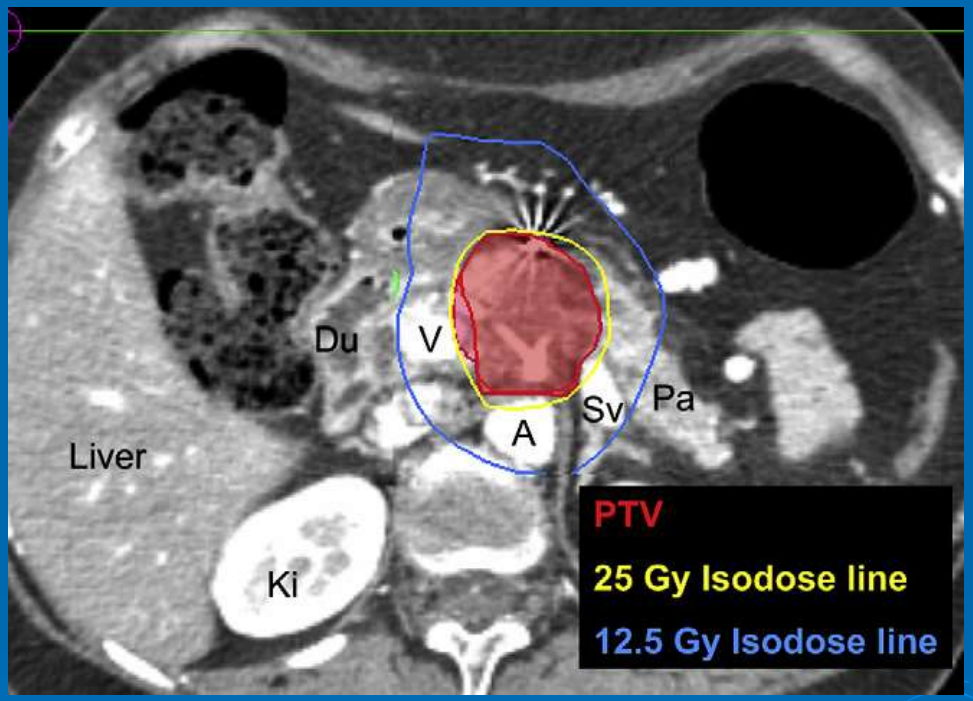


Fig. 4. Cumulative DVHs of the adaptive plans using the AAP method (solid lines) and prostate COV alignment (dashed lines) for patient 5. Each of the DVHs shown is derived from the cumulative dose distributions of 8 repeat CT scans and was evaluated with the manual contours on simulation CT.

ART: pancreatic cancer



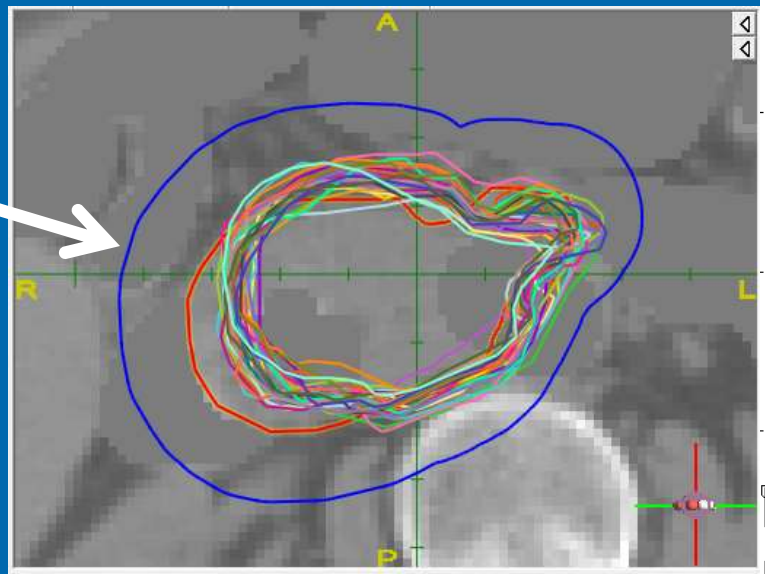


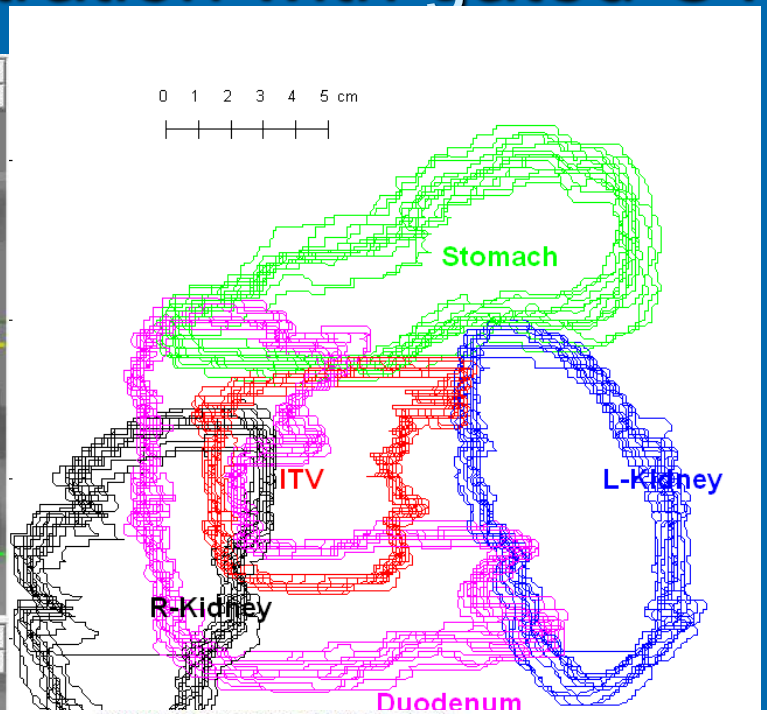
Prognosis: 5% at 5 year

Inter-fractional Variations: pancreas head

Soft-tissue based registration with gated CT

PTV
10 mm
margin





Radiotherapy and Oncology 100 (2011) 370–374

Contents lists available at SciVerse ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Adaptive radiotherapy

Development of an online adaptive solution to account for inter- and intra-fractional variations ☆

X. Allen Li *, Feng Liu, An Tai, Ergun Ahunbay, Guangpei Chen, Tracy Kelly, Colleen Lawton, Beth Erickson

Department of Radiation Oncology, Medical College of Wisconsin, Milwaukee, WI, USA

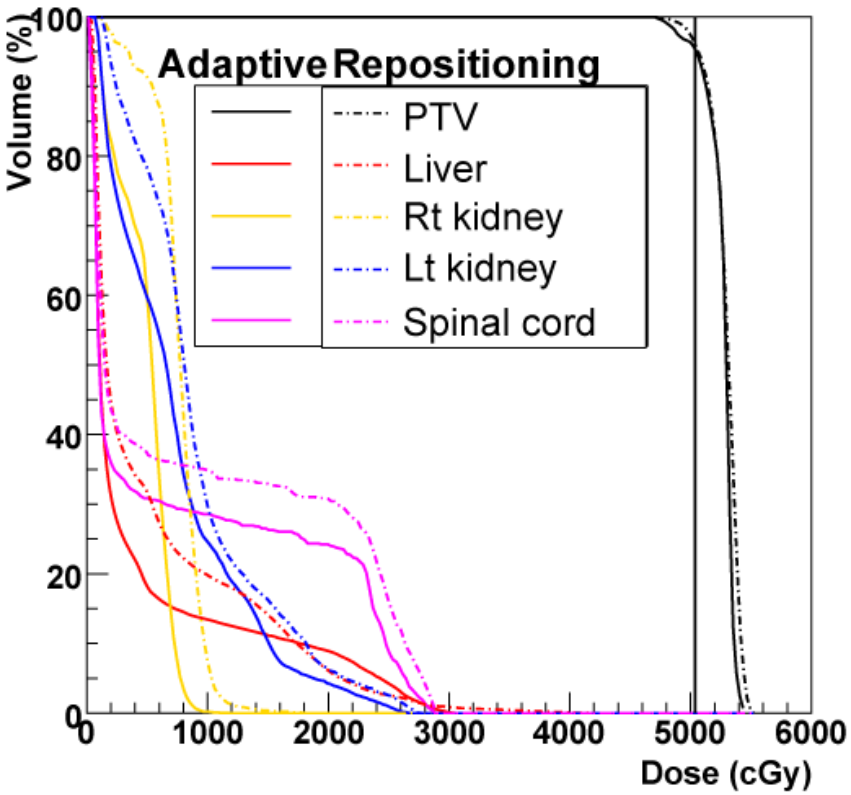
Major Challenge of Online ART for Pancreas

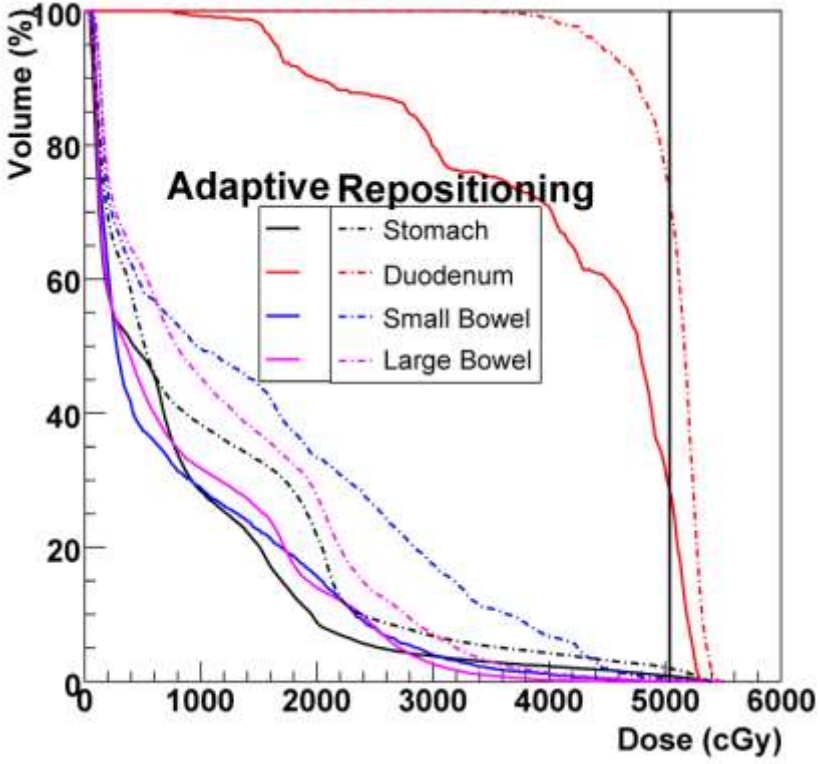
Target/OAR delineation

- difficult for auto-segmentation due to large deformations and insufficient soft-tissue contrast
- a large number of OARs (duodenum, bowels, stomach, kidneys, liver, spinal cord)

Online Adaptive Replanning

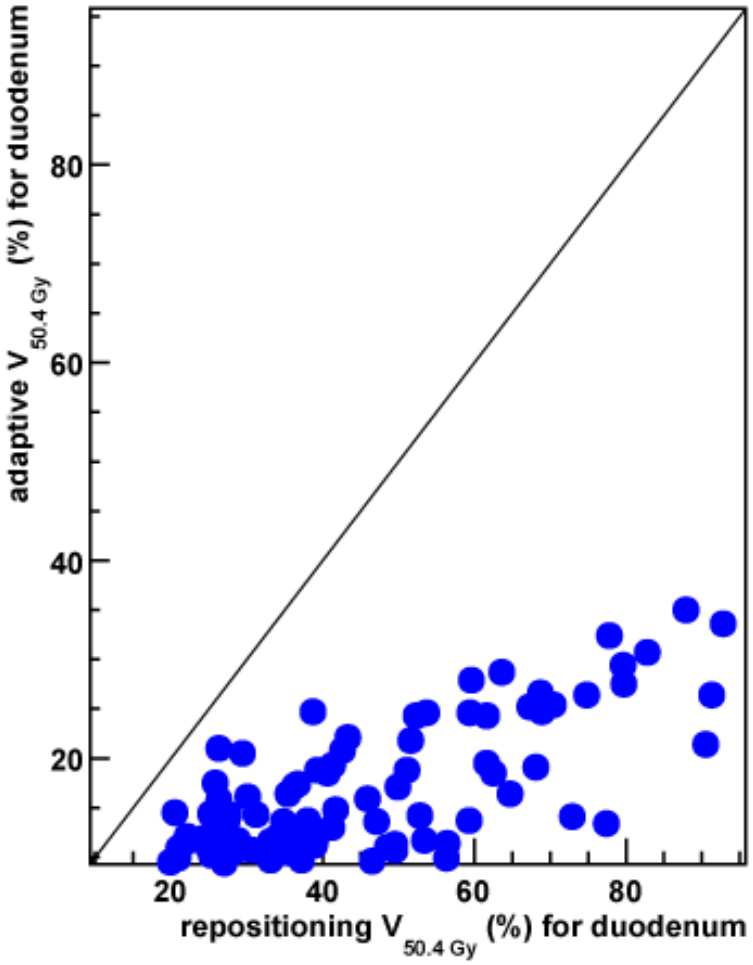
ART allows smaller (e.g., 5mm) PTV margin, compared to repositioning (e.g., 10 mm margin)

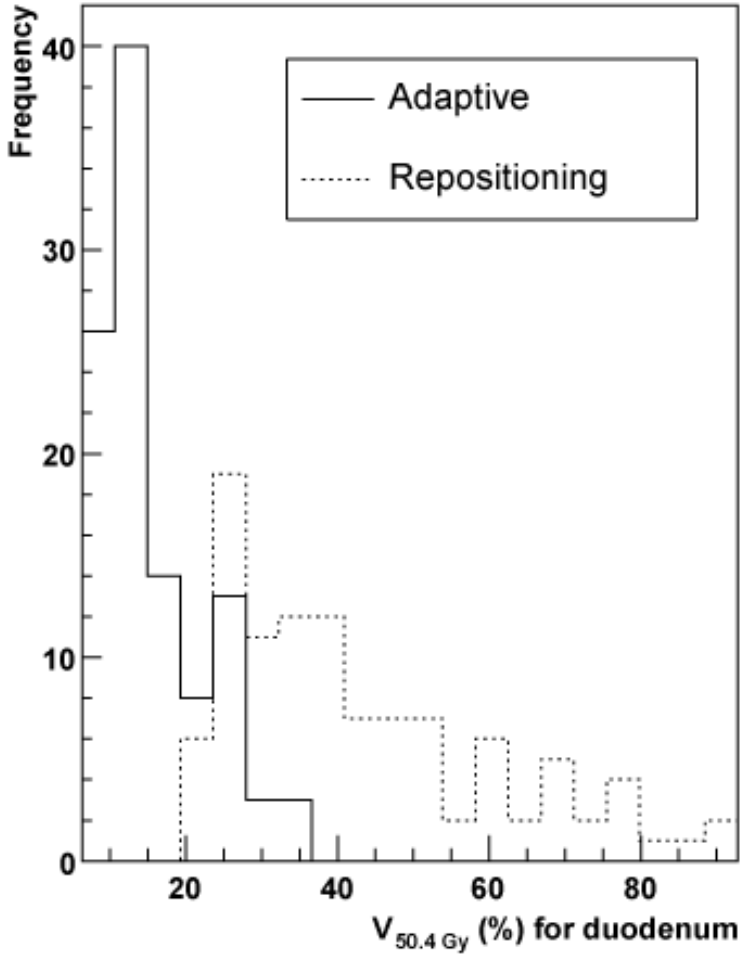




Adaptive v.s. Repositioning

- Duodenum ***10 cases***





Dosimetric Impact of RT delivery technologies on pancreas RT

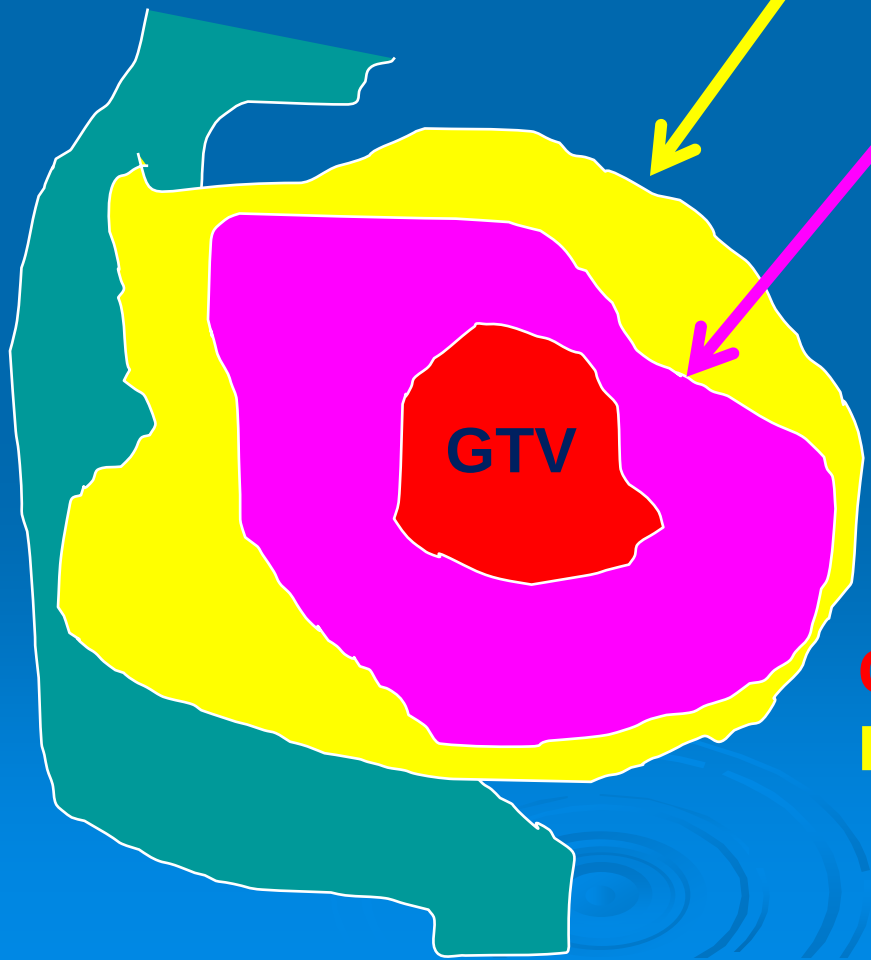
	ART gating	IGRT gating	IGRT No gating	no IGRT no gating
Duodenum V50.4	**19%**	**42%**	**66%**	**72%**
L-Kidney V15	**8%**	**15%**	**22%**	**19%**
R-Kidney V15	**14%**	**23%**	**32%**	**35%**
Large Bowel V45	**0.4%**	**3%**	**8%**	**11%**
Stomach V45	**1%**	**4%**	**9%**	**11%**
Liver V30	**2%**	**6%**	**13%**	**17%**
Small Bowel V45	**1%**	**4%**	**10%**	**12%**

Average of 5 patients

Dose escalation for unresectable pancreatic cancer

- MRI/PET defined GTV
- 4DCT based planning
- Daily gated CT guided gated delivery
- Hybrid ART

PTV = pancreatic head
+ suspicious nodes
+ 5 mm margin

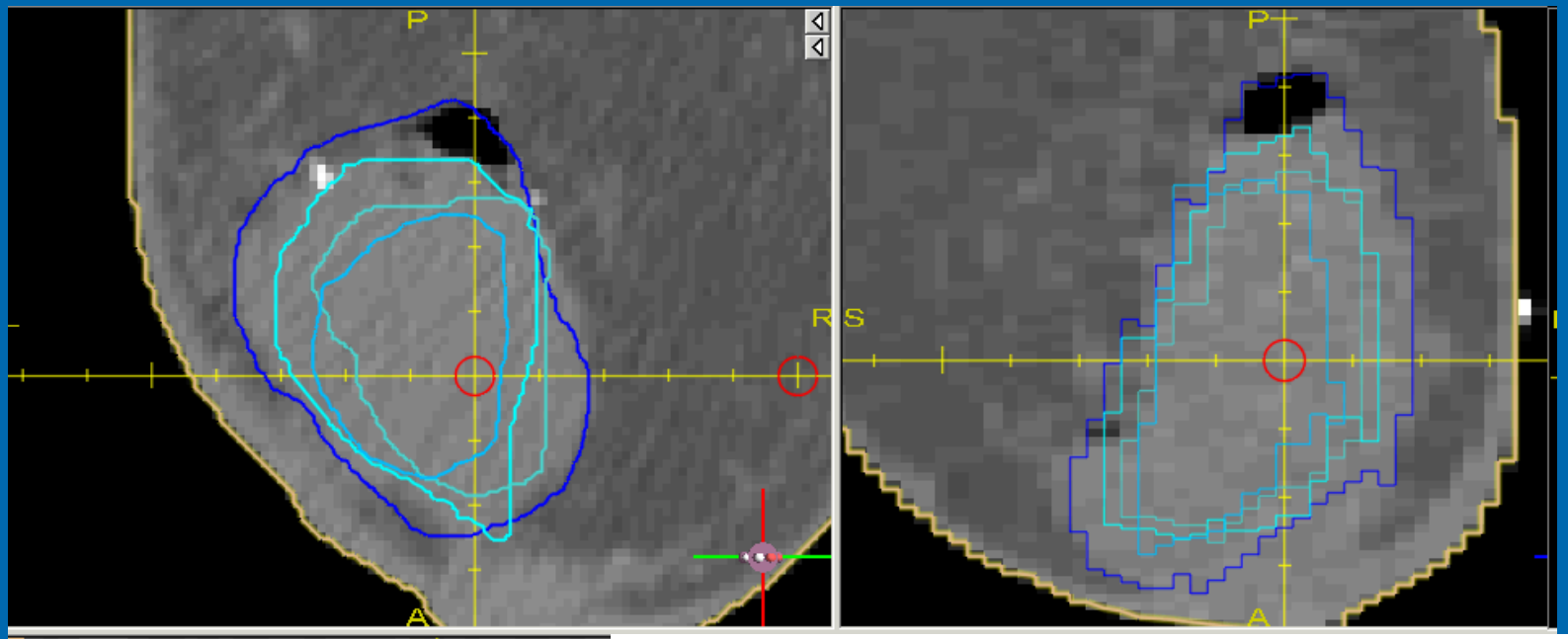


GTV: 31x2.25=69.75Gy
PTV: 33x1.76=54.56Gy

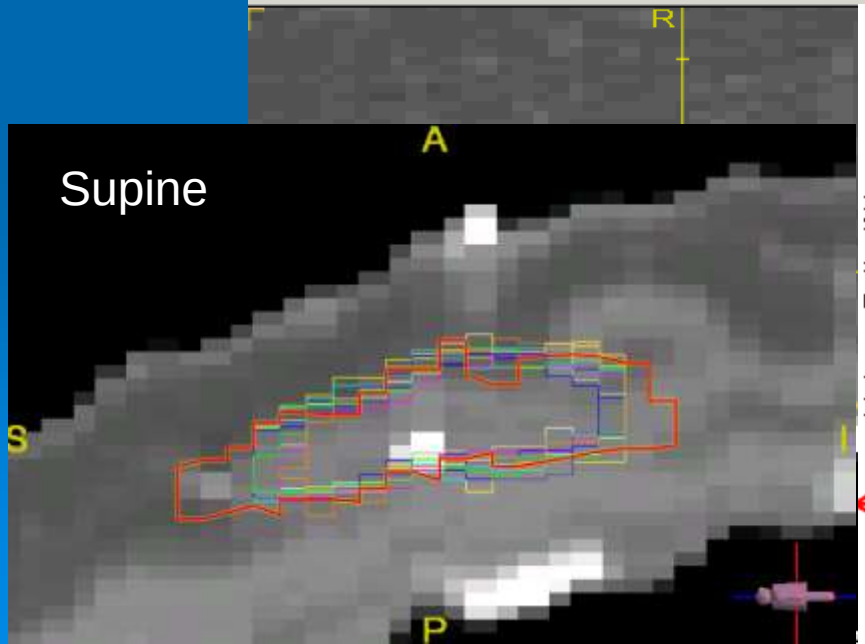
ART for breast

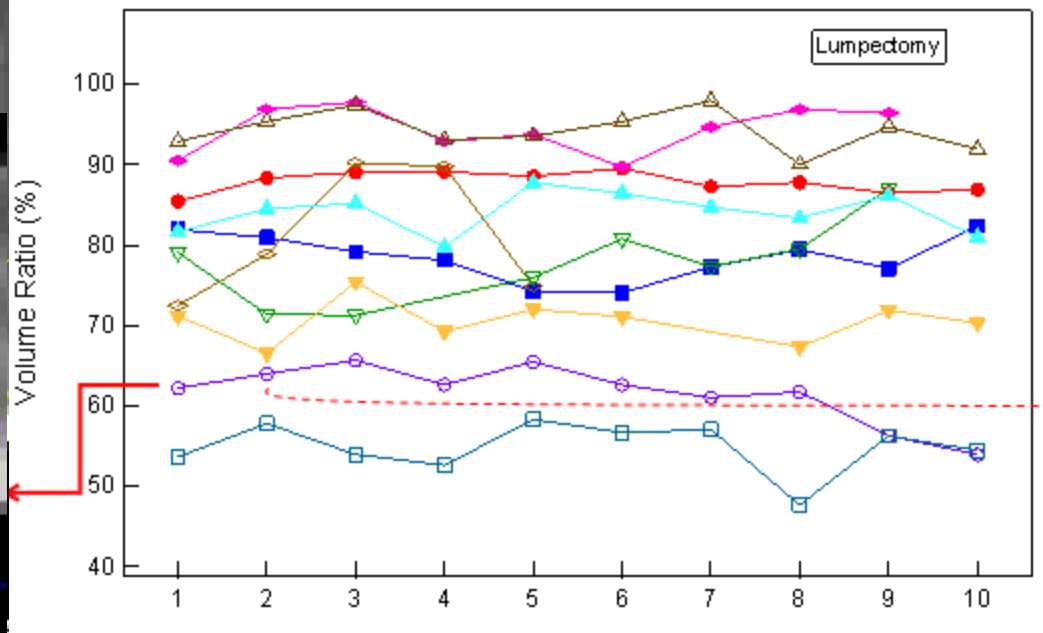
Lumpectomy cavity volume and shape change

Prone



Supine

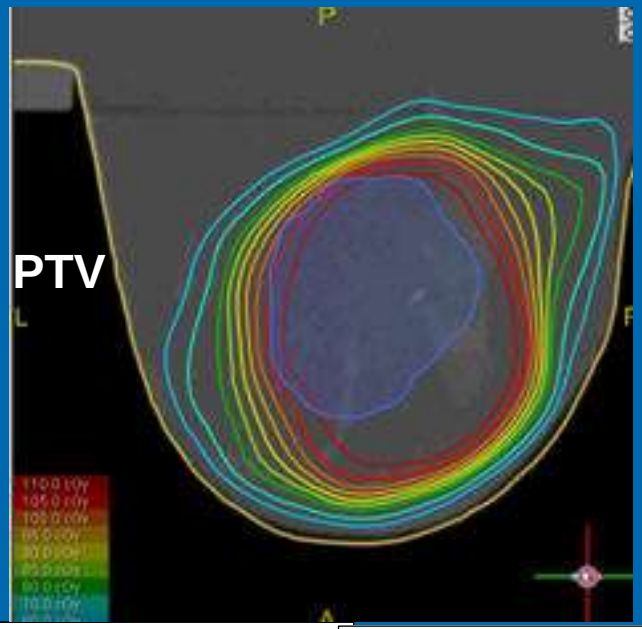




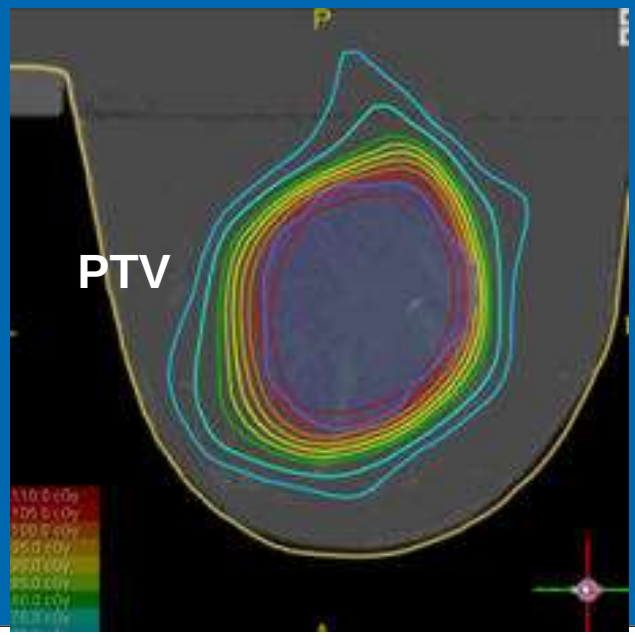
ART for PBI

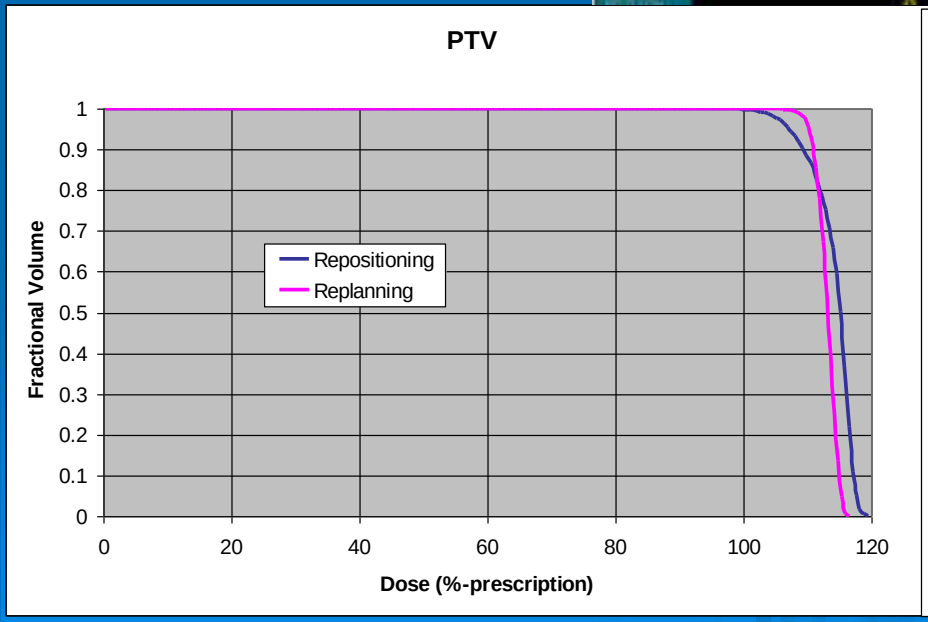
- Improve target conformity
- Reduce skin dose

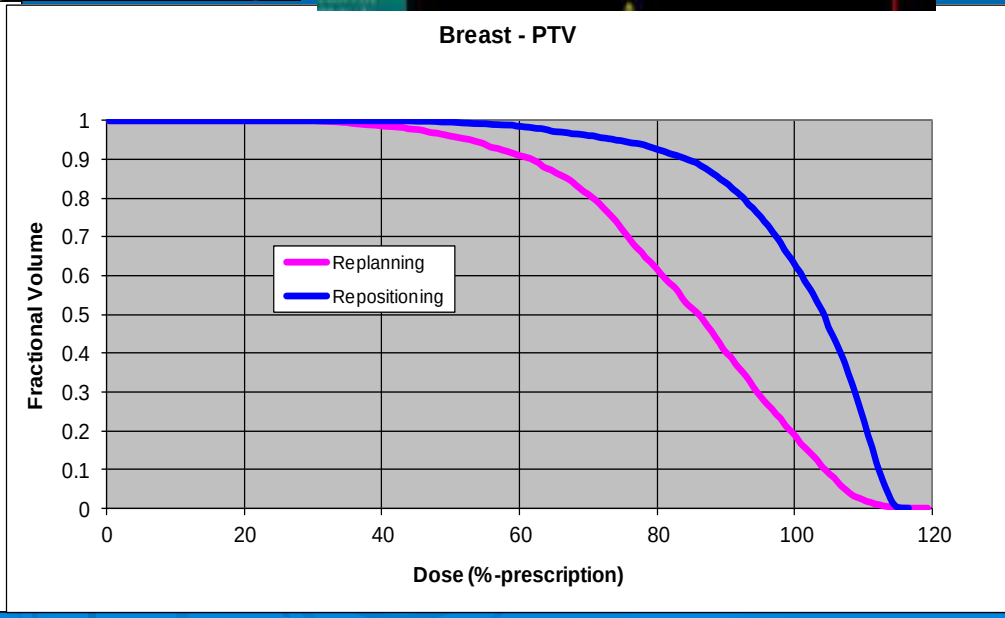
Repositioning



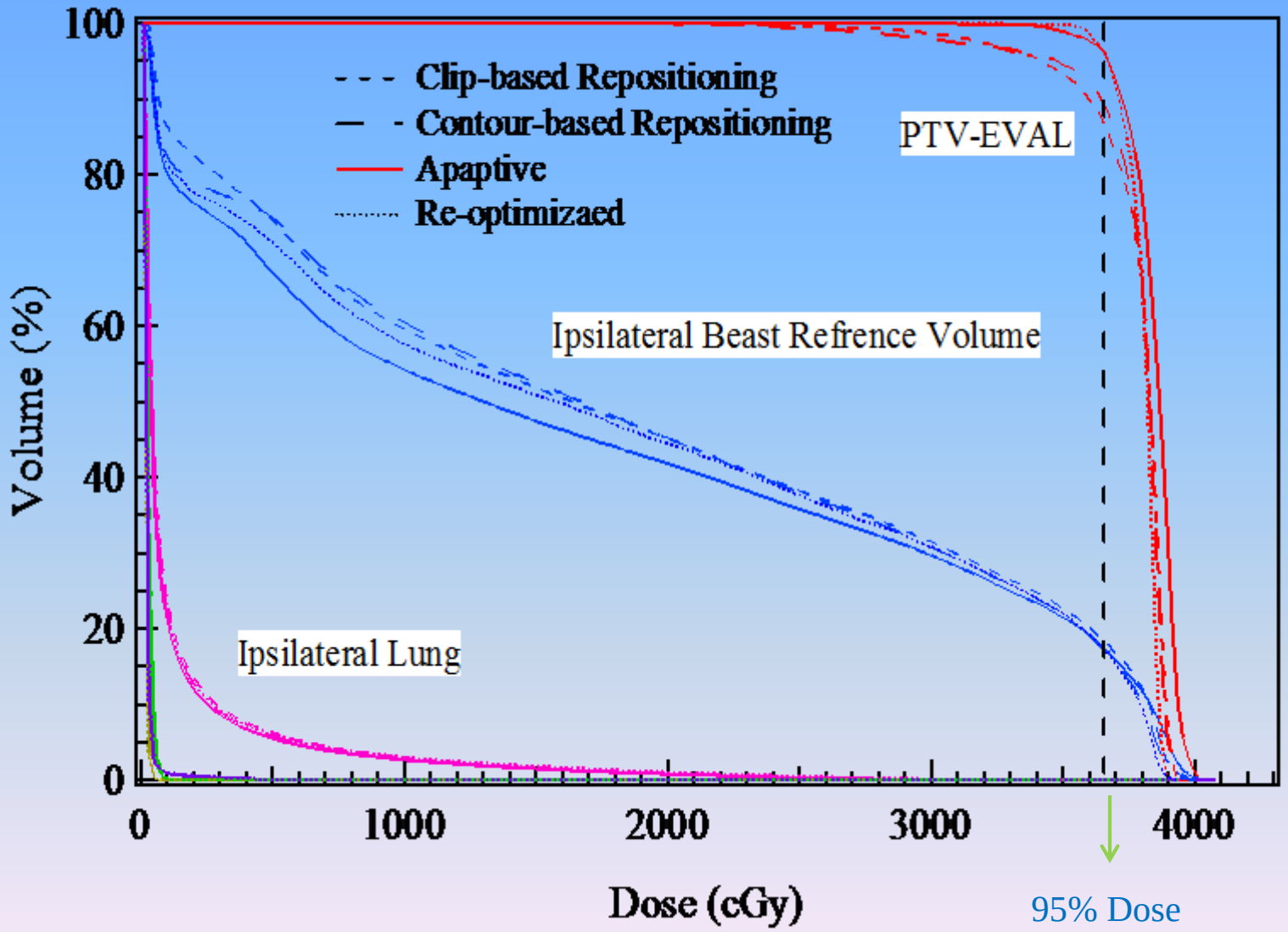
Replanning





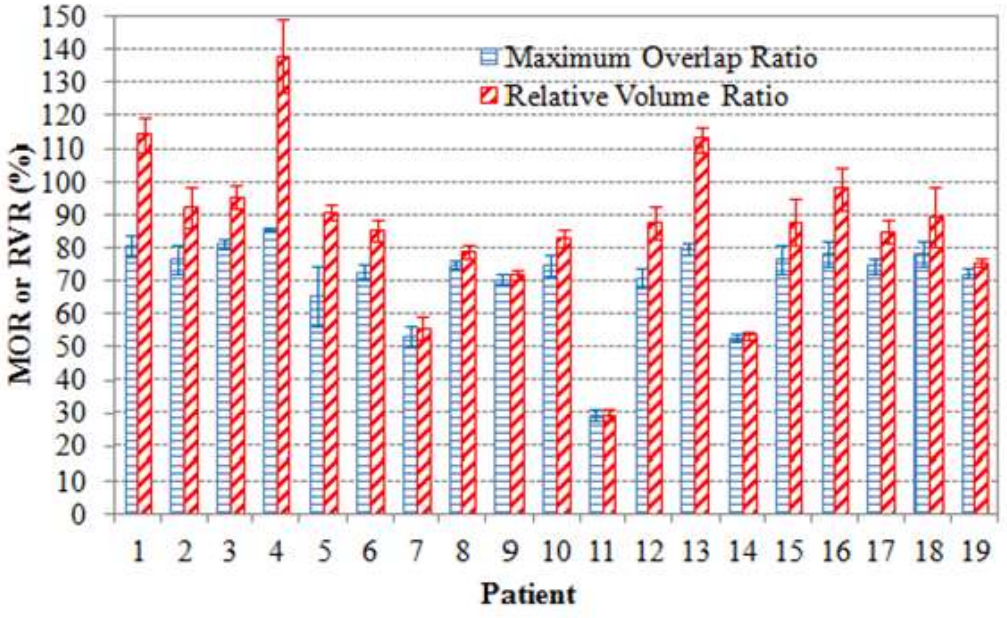


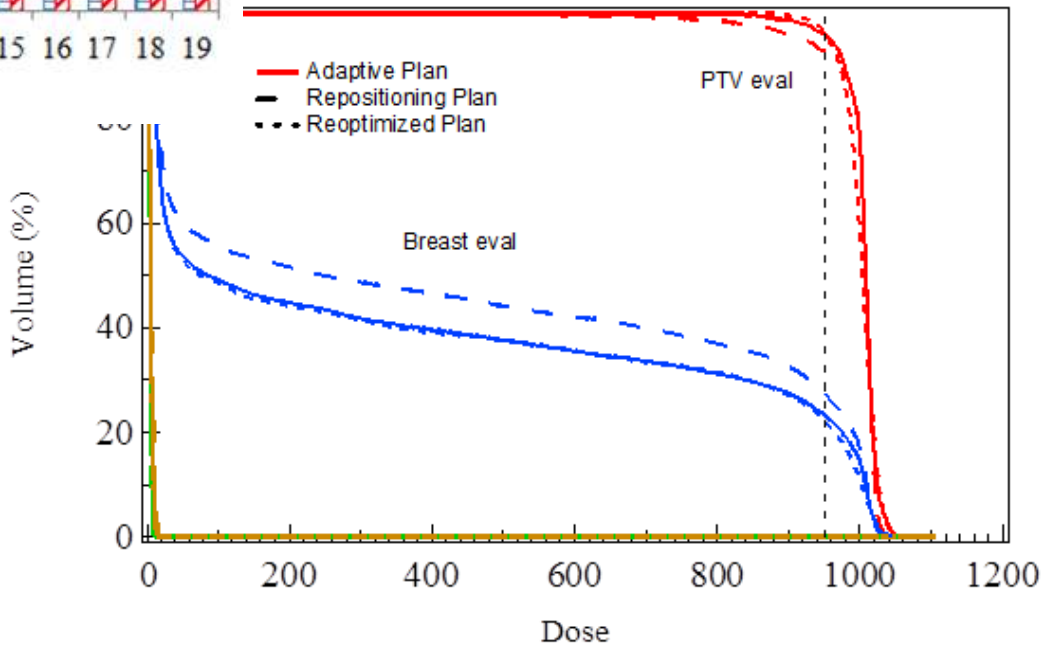
Repositioning vs Adaptive Plan: Supine



Breast WBI + ART for boost

Changes in lump cavity between daily CT at boost and plan CT.

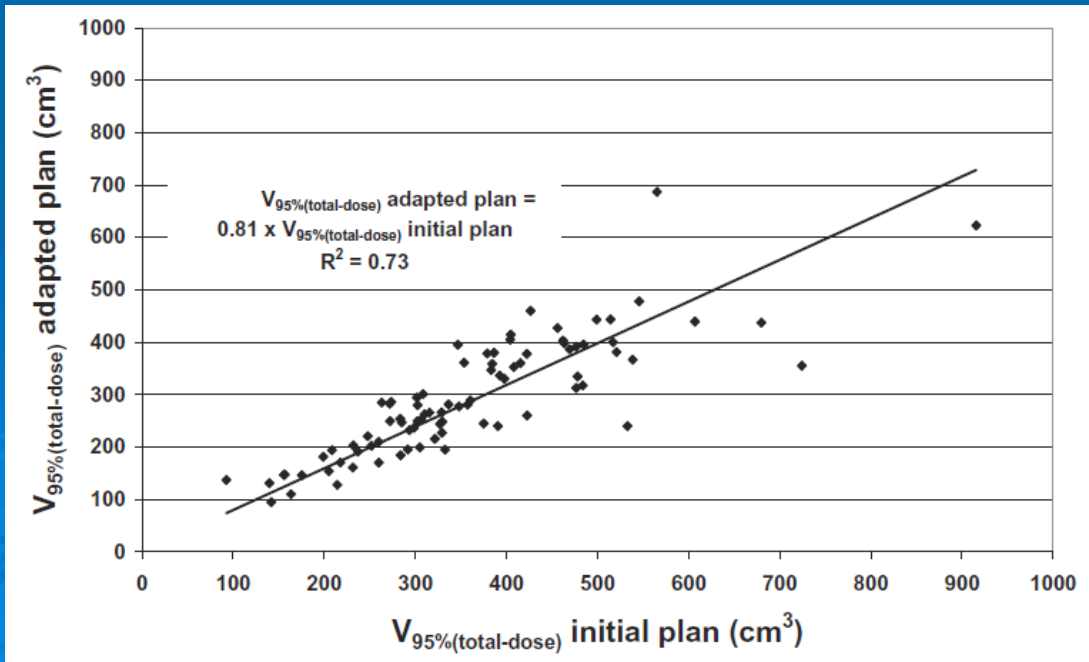




Structure	Quantity	IGRT	ART
PTV eval	$V_{95\%}$	93.7%	96.0%
Breast eval	$V_{50\%}$	42.3%	39.3%
Breast eval	$V_{100\%}$	18.6%	17.0%
PTV eval	CI	2.0	1.8

Offline ART for IMRT SIB

- ART replanning based on new CT at 10th fr (28 fr total)
- Eligibility:
  - lump cavity > 30 cc
- Findings
  - 9% of patient eligible
  - significant reduction of high dose volume



Hurkmans et al, Radiother Oncol. 2012;103:183-7

A study in design at MCW

Whole breast irradiation + ART boost

- ART plan based on CT one day before boost; boost treated with ART plan

- Eligibility:
  - lump cavity > 30 cc
  - V54Gy > 40%

- End points:
  - Primary: reduction of fibrosis
  - Secondary: reduction of local recurrence

Summary

- The current standard of IGRT (repositioning) can not address volume change, deformation and rotation.
- ART (Online, offline, hybrid) not only address only anatomy changes (translational and rotational shifts and deformation), eliminating repositioning, but can also potentially consider patient specific treatment response.
- As demonstrated on tumor sites of prostate, pancreas and breast, ART replanning leads to improved target coverage and/or normal tissue sparing.
- The online ART enables "**image-plan-treat**", particularly important for hypofractionations, SBRT.
- ART begins moving into clinic for various tumor sites.