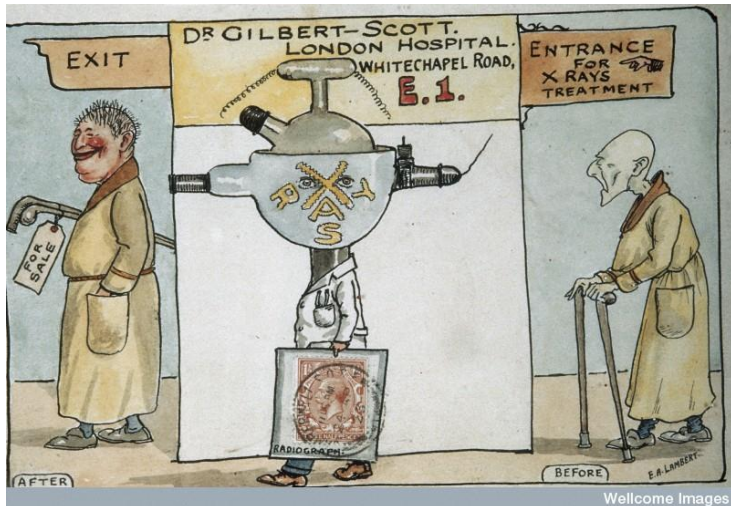




XVI. National Medical Physics Congress

Antalya, 29-30 October, 2017

Personalized Adaptive Radiotherapy



Kiki Theodorou

Professor of Medical Physics

Medical School, University of Thessaly



Adaptive Radiotherapy

Early Diagnosis

Local Control

Less Side Effects

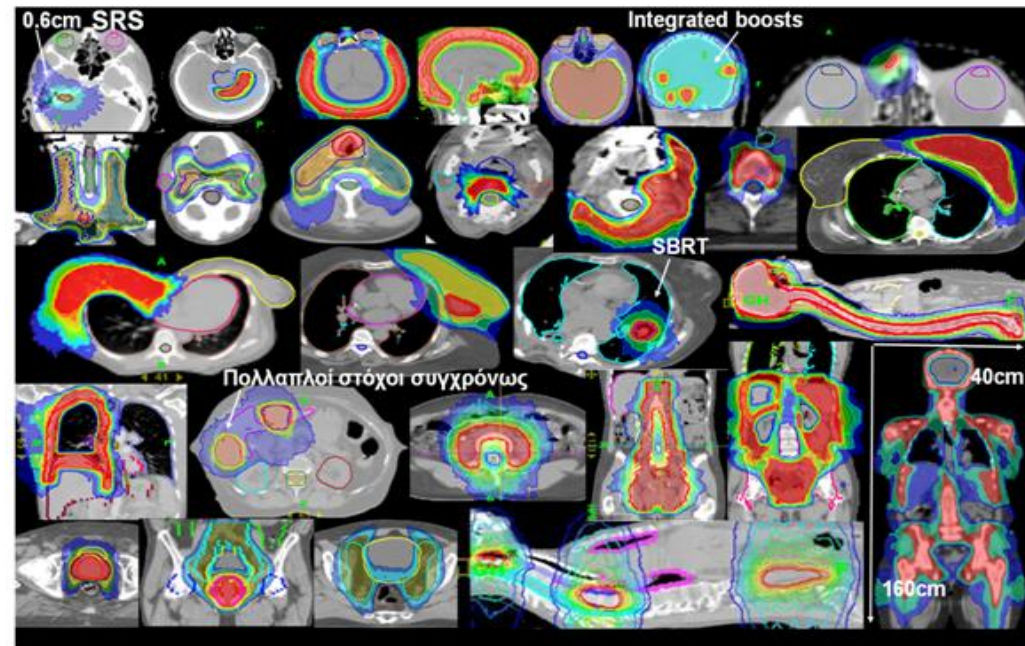
Intensity
Modulated
Radiation Therapy
(IMRT)

Image Guided
Radiation
Therapy (IGRT)

Dose Escalation/
Hypo-fractionation

Adaptive Radiation
Therapy

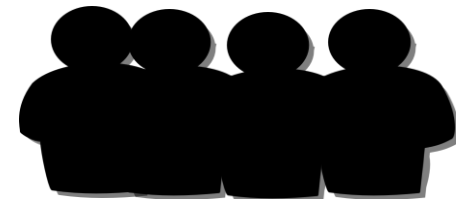
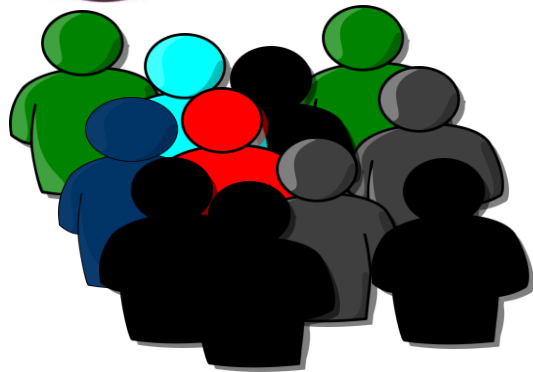
- Multi-modality imaging
- New Technology
- New Radiobiological data (?)





Personalized Radiotherapy

Population based radiotherapy

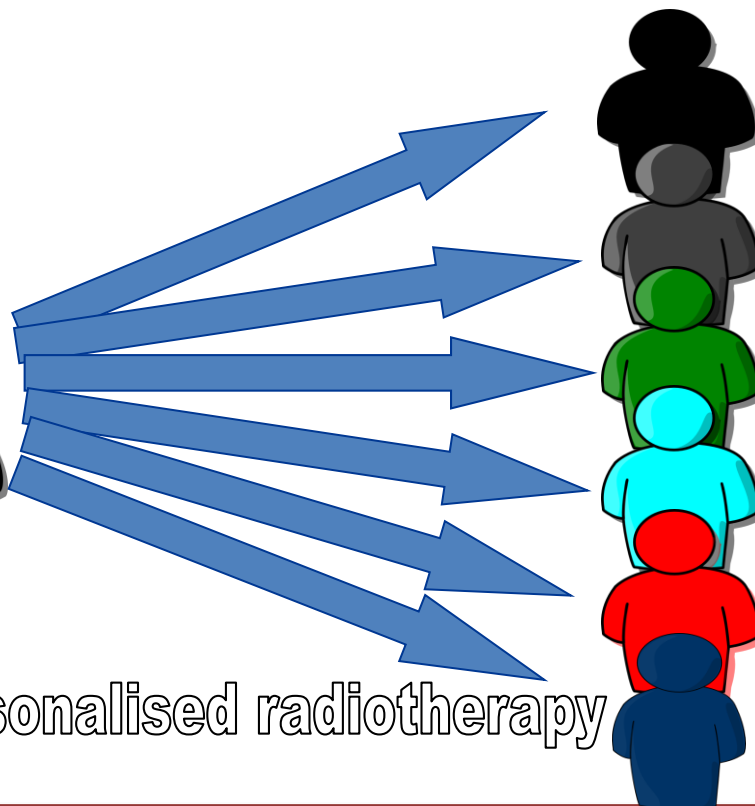
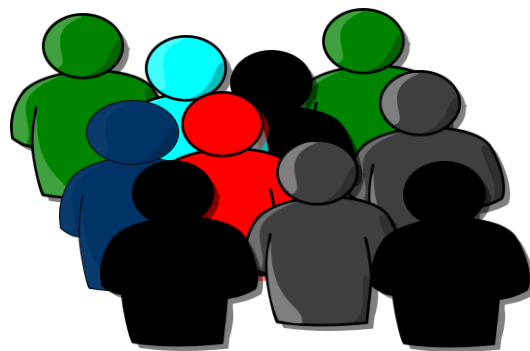


**Personalised
Radiotherapy**

Individualised plan

***Image-guided
treatment***

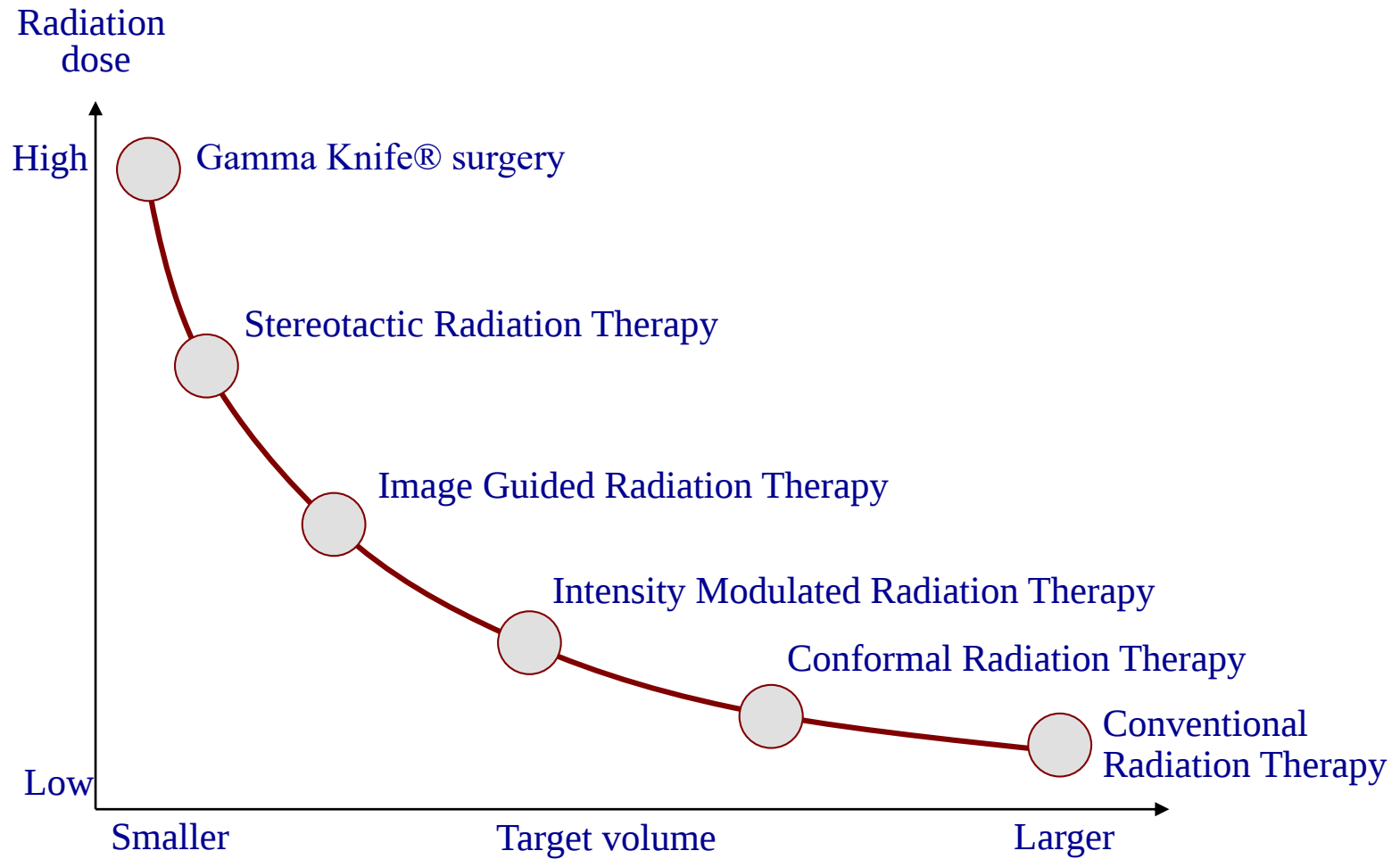
Plan adaptation as
required



Personalised radiotherapy



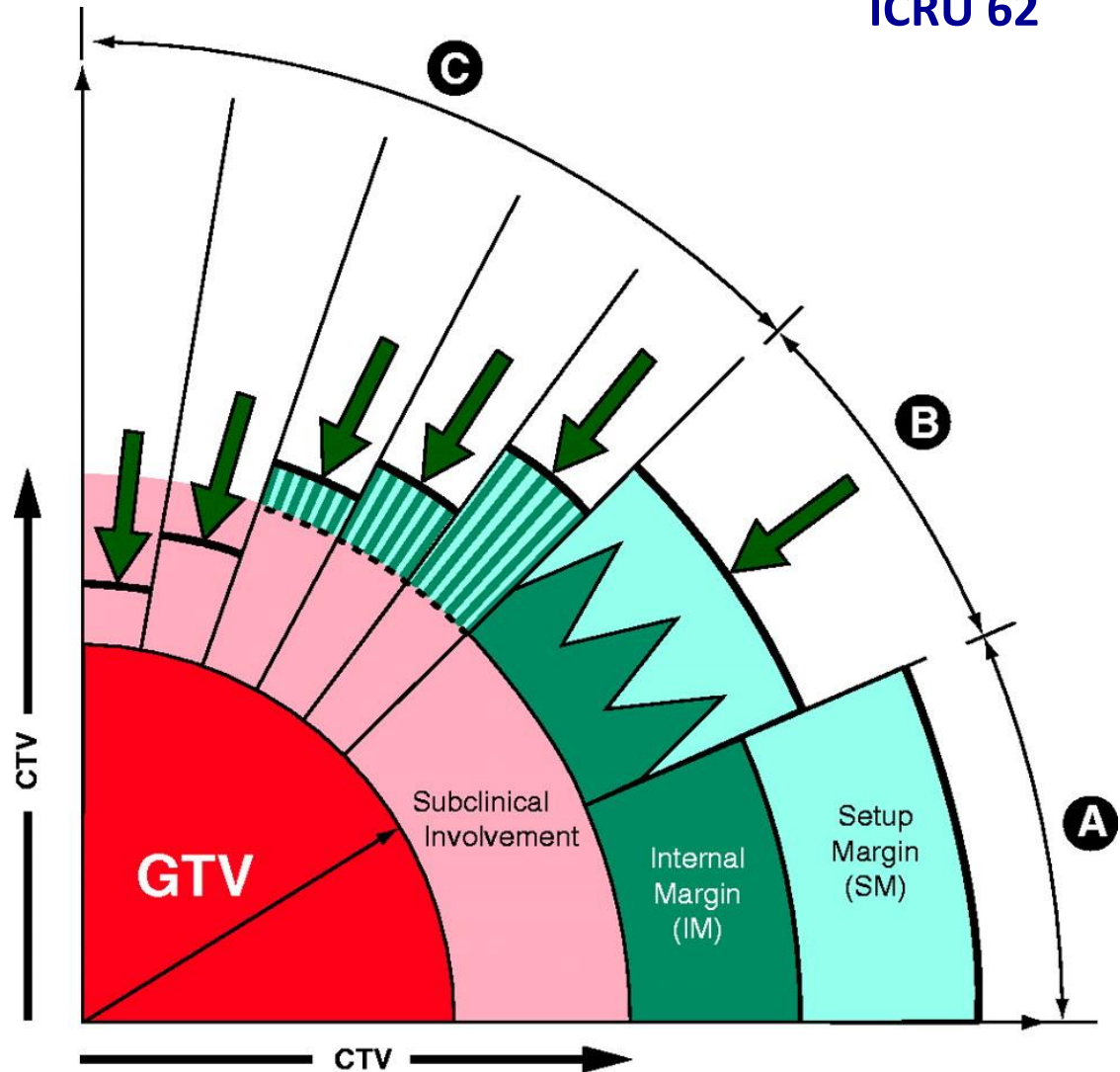
Target Volume v.s. RT Technique





Limitation of the target's margin

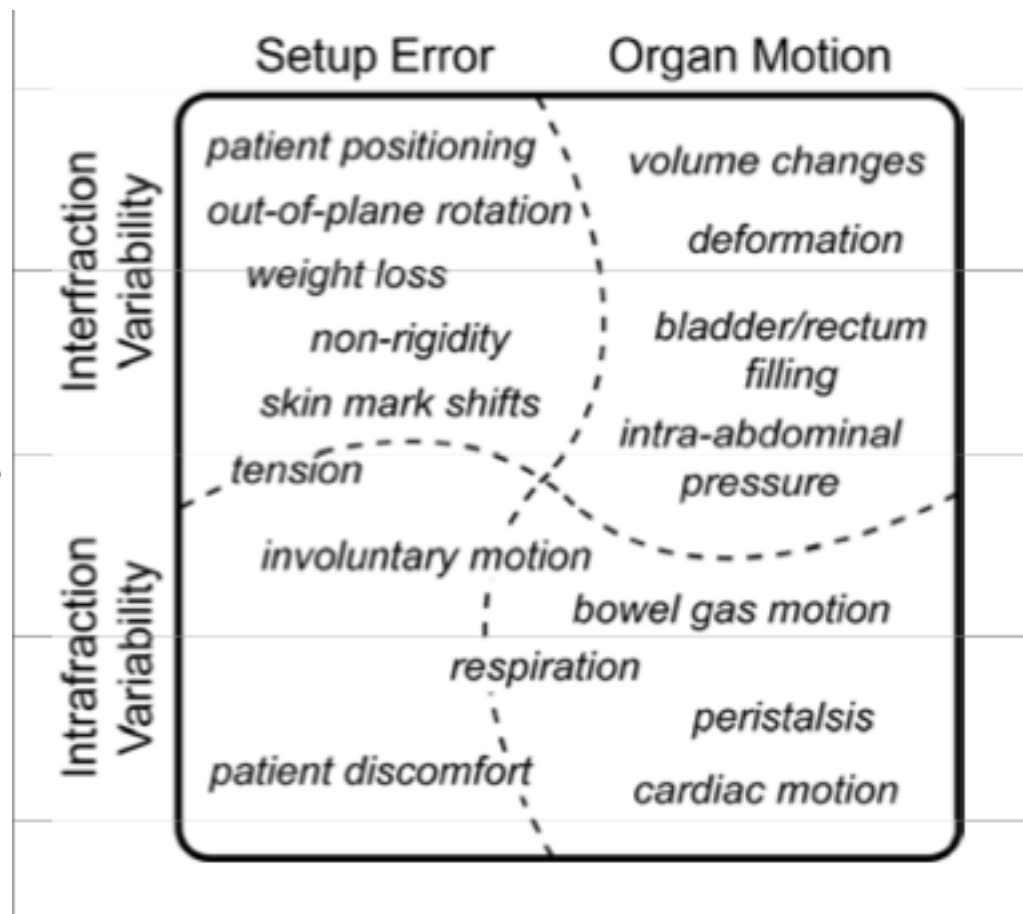
ICRU 62





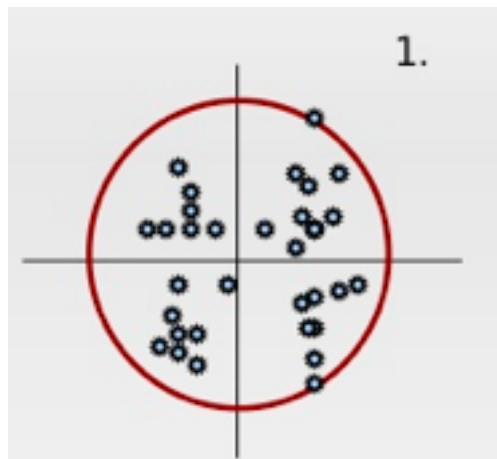
Target Definition – Sources of errors

- Setup Inaccuracy
- Internal Organ Motion
- Change/ Deformation of the target



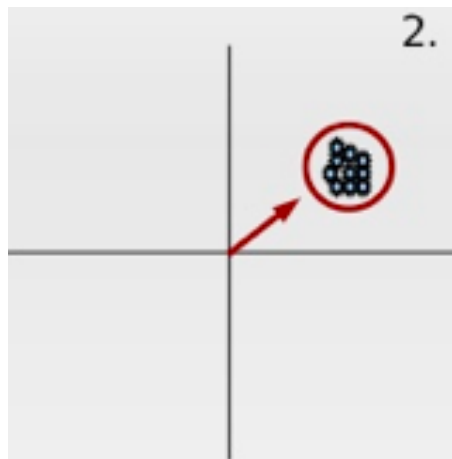


Target margins



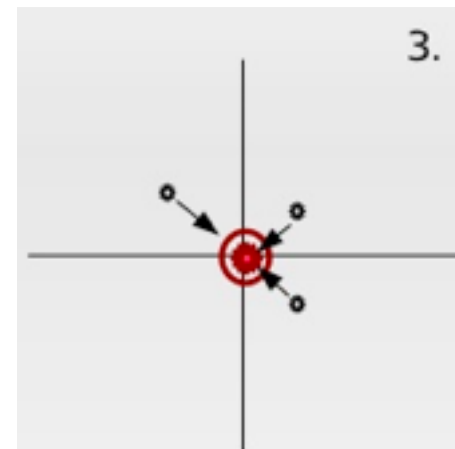
•Conventional R_x

- › Sample Population based margins
- › Accommodates variations of setup for the populations
- › No or infrequent imaging
- › Largest margin



•Offline ART

- › Individual patient based margins
- › Frequent imaging of patients
- › Estimated systemic error corrected based on repeated measurements
- › A small margin kept for random error
- › Plans adapted to average changes



•Online ART

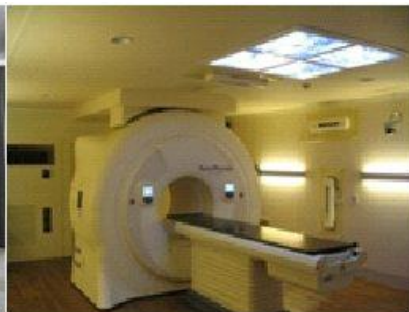
- › Individual patient based margins
- › Daily imaging of patients
- › Daily error corrected prior to the treatment
- › Smallest margin required
- › Plans adapted to the changing anatomy daily!



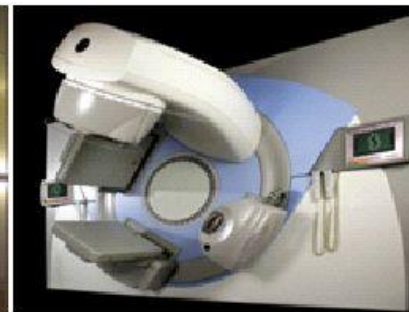
IGRT – Current Technology



(a) Siemens (CT on Rail)



(b) Tomotherapy



(c) Elekta



(d) Cyberknife



(e) VERO



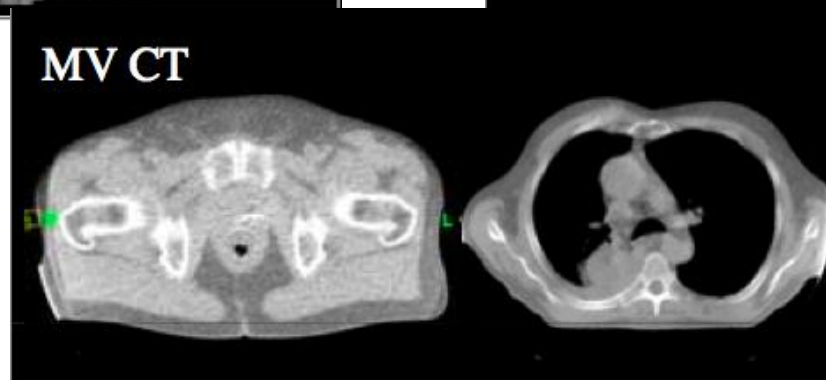
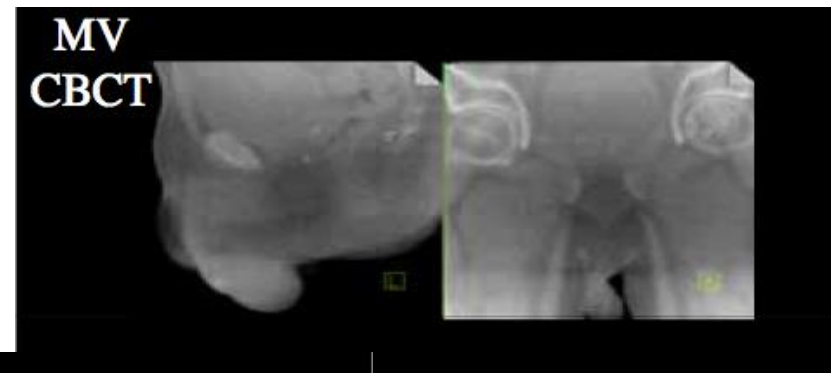
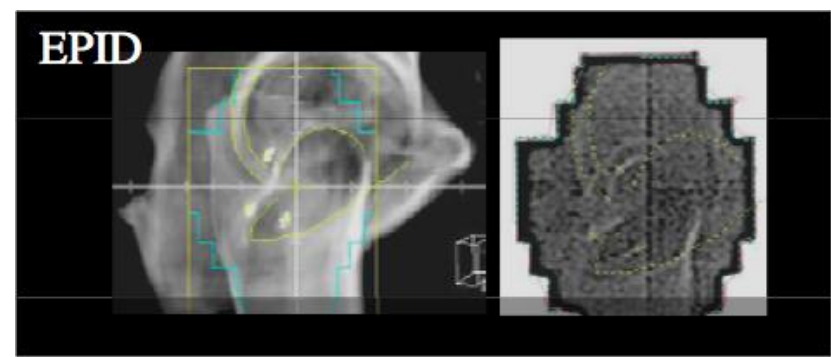
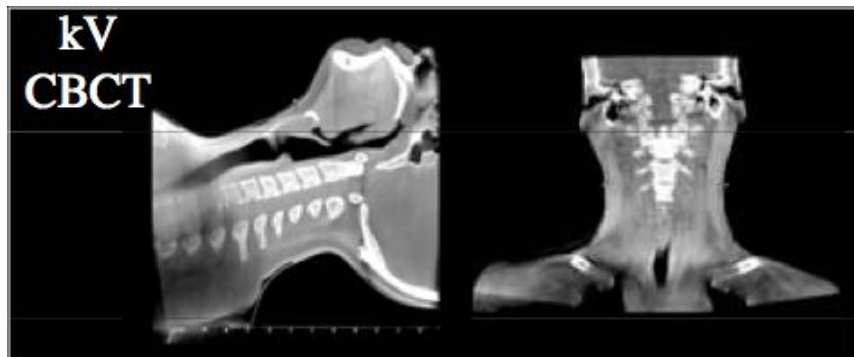
(f) Varian



(g) Novalis



IGRT - Imaging





IGRT v.s. Adaptive Radiotherapy

Definition

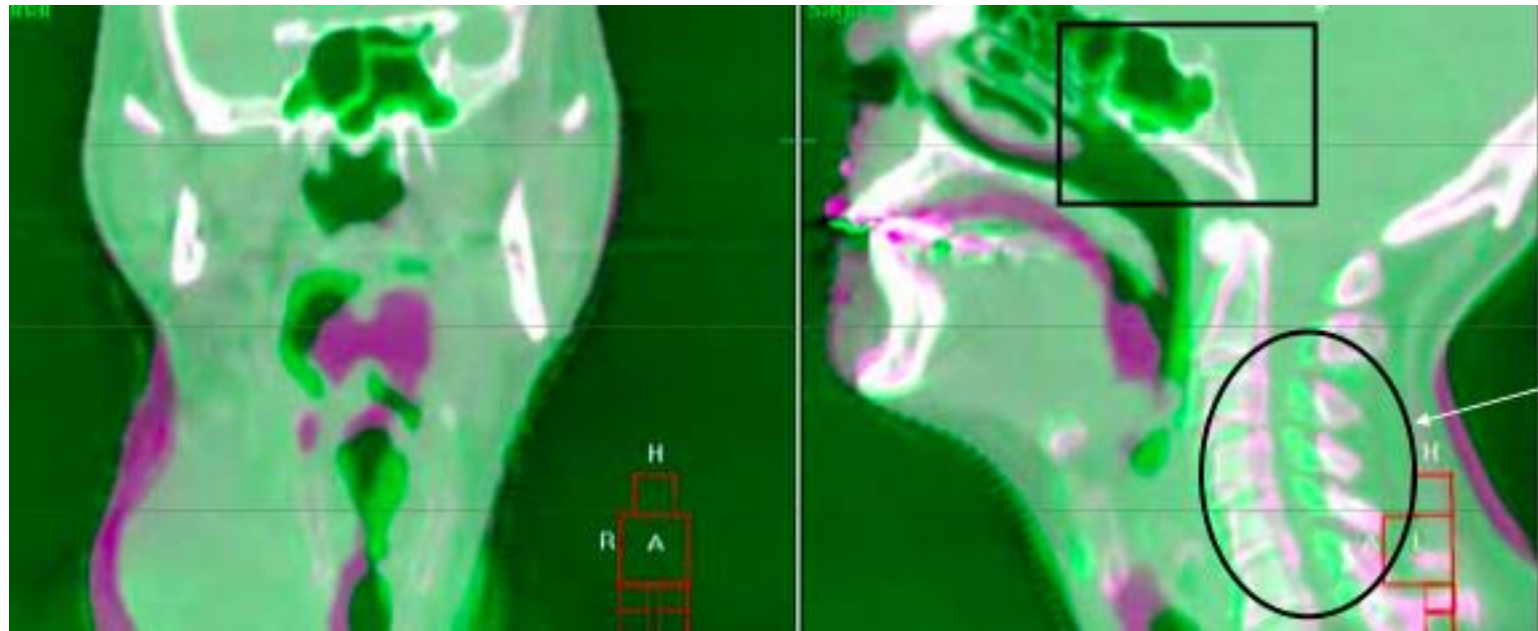
“Image Guidance” is commonly referred to a process to re-position the patient without modifying the initial treatment plan

“Adaptive RT” involves the modification of the initial plan



IGRT – Patient Setup Correction

Wrong patient positioning

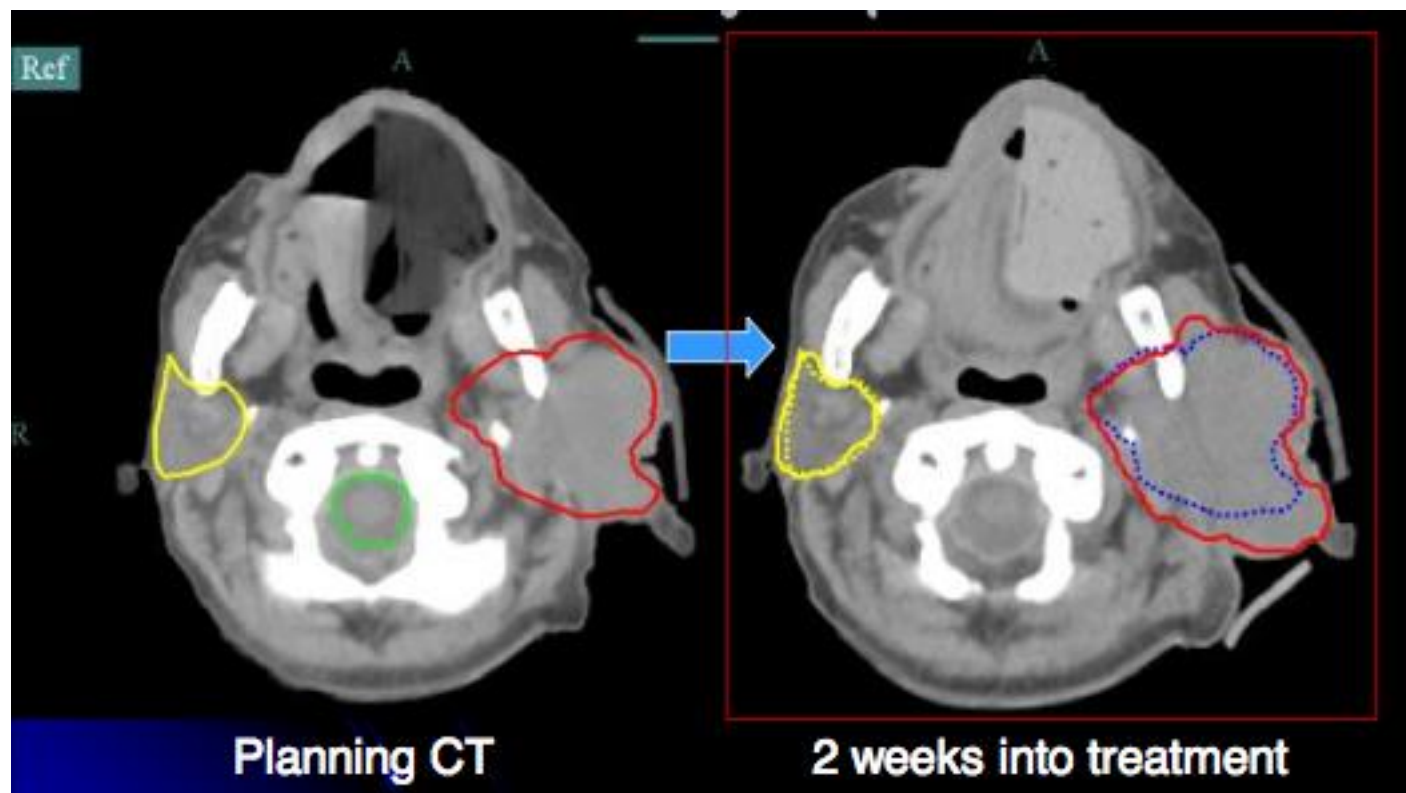


Can't be corrected with couch shift



IGRT – Patient Setup Correction

Target Increase

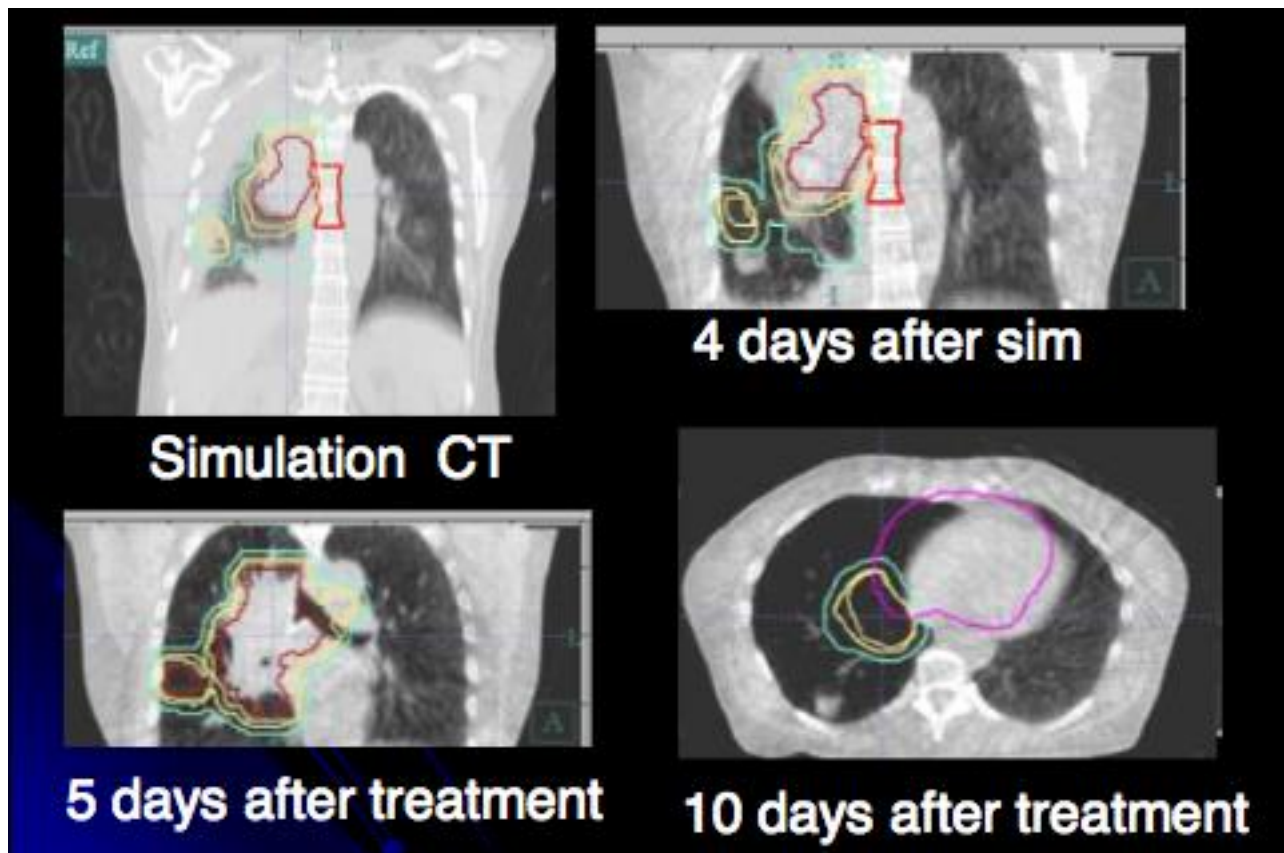


Can't be corrected with couch shift



IGRT – Patient Setup Correction

Rapid Changes can occur early



Can't be corrected with couch shift



IGRT v.s. Adaptive Radiotherapy

Definition

“Image Guidance” is commonly referred to a process to re-position the patient without modifying the initial treatment plan

“Adaptive RT” involves the modification of the initial plan

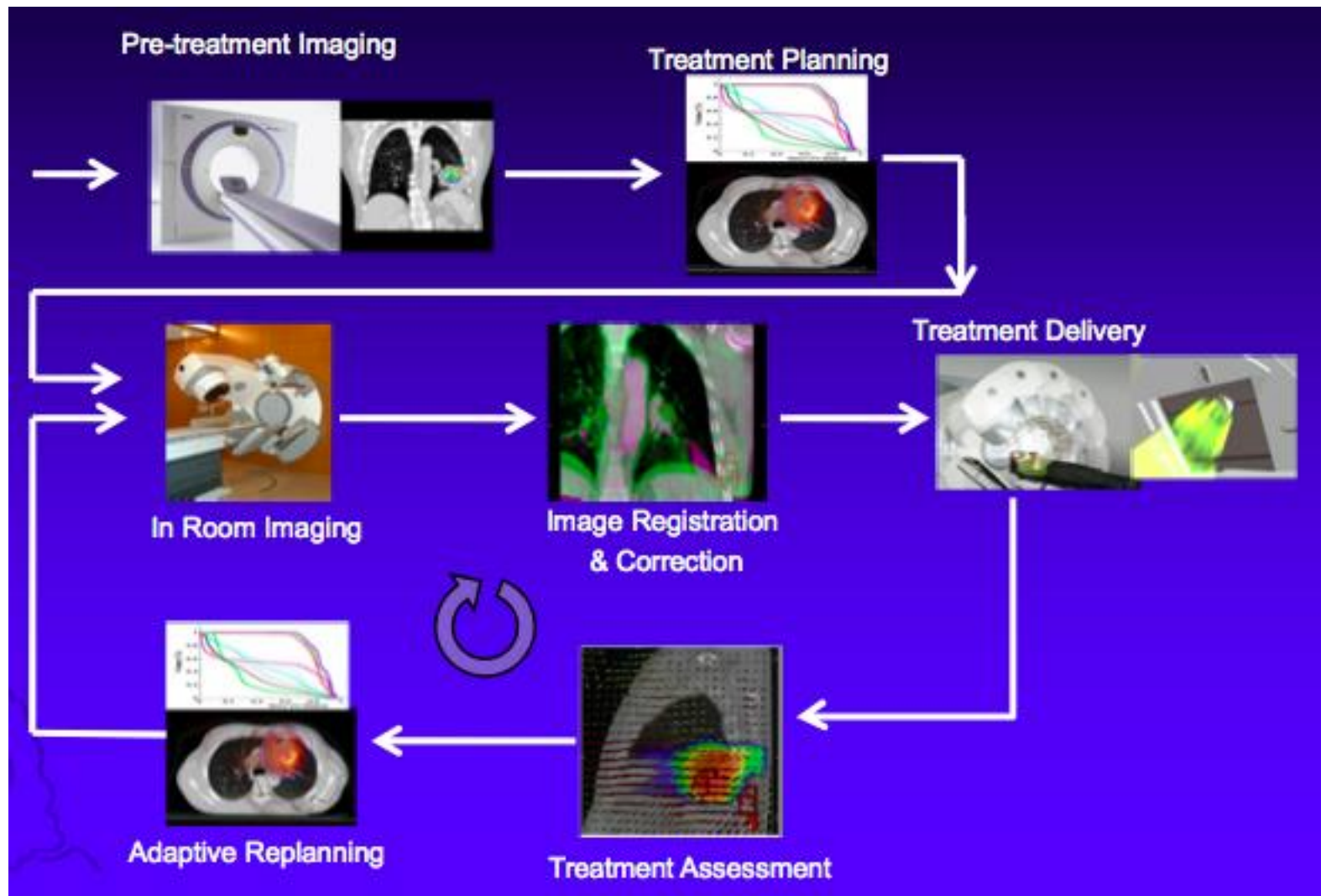


Adaptive Radiotherapy

TYPES OF ART	Examples
Motion adaptive	Beaumont's ART process, 'Plan of the day' IMRT
Biological adaptive	Theragnostic planning
Response adaptive	Mid-treatment response evaluation, shrinkage of GTV & OAR
Time adaptive	Mid-course CT and planning

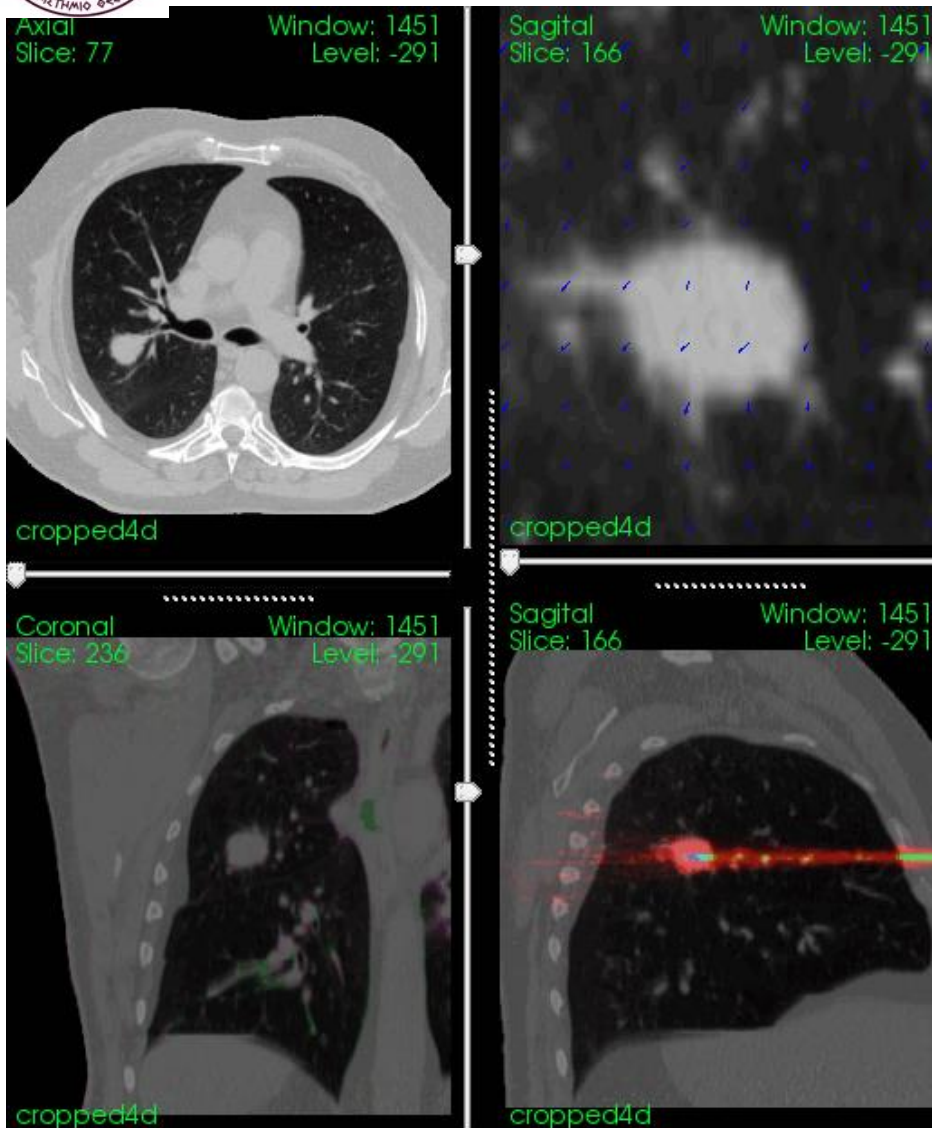


Adaptive Radiotherapy- Procedure



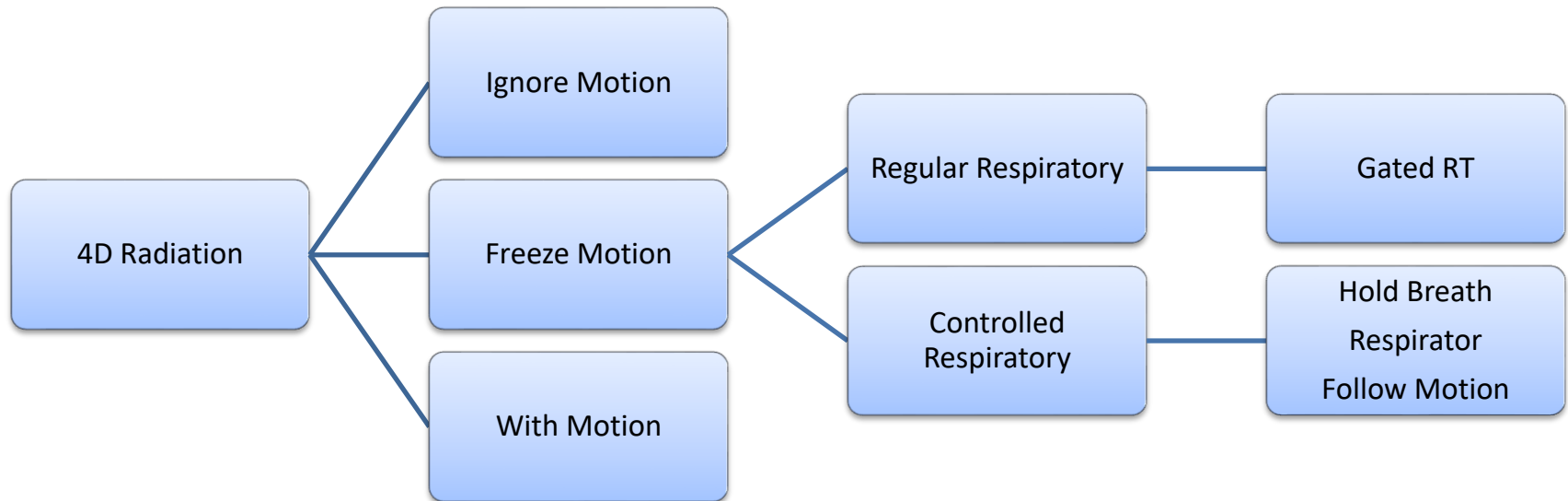
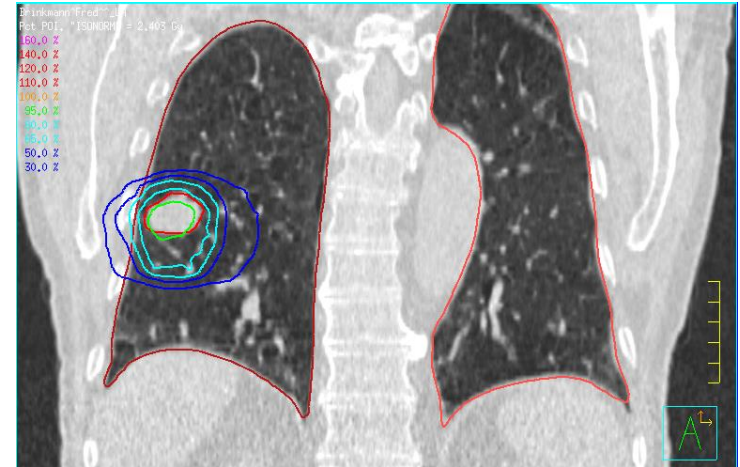


IGRT/Adaptive – Organ Motion





IGRT/ART – Organ Motion



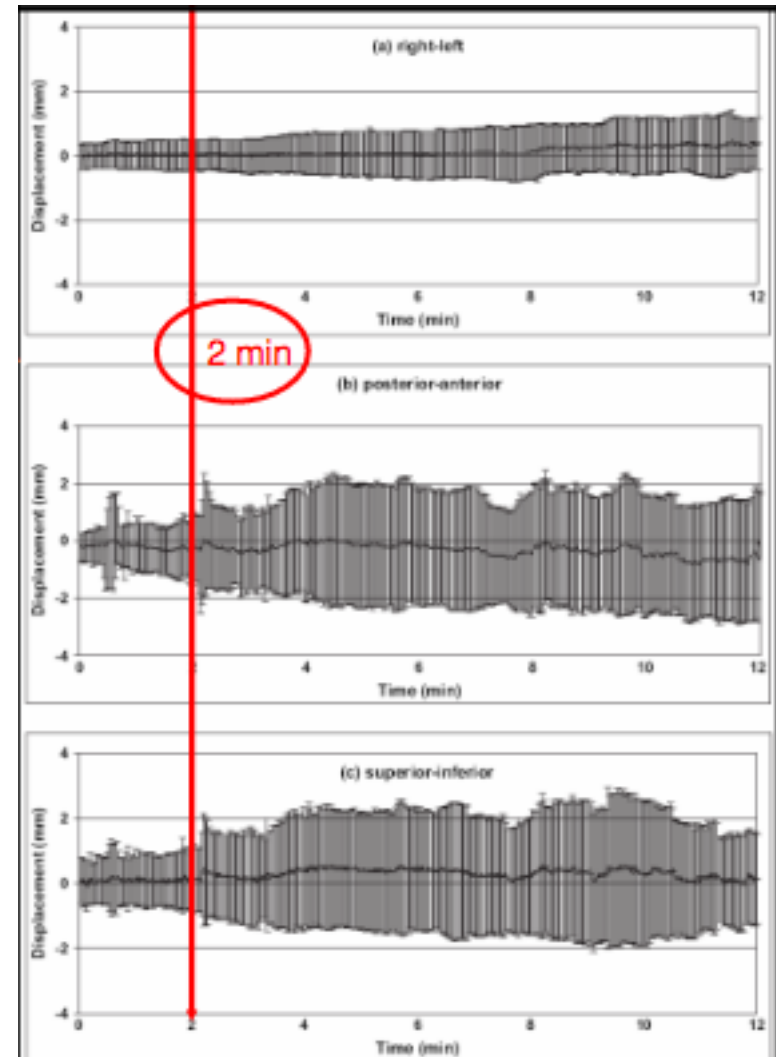


IGRT/ART – Organ Motion

- **Move couch electronically to adapt to the moving tumor**
 - Exac trac 6D Robotic couch
- **Move a charged particle beam electromagnetically**
 - RPM system
- **Move a robotic lightweight linear accelerator**
 - Cyber knife
- **Move aperture shaped by a dynamic MLC**
 - Calypso system

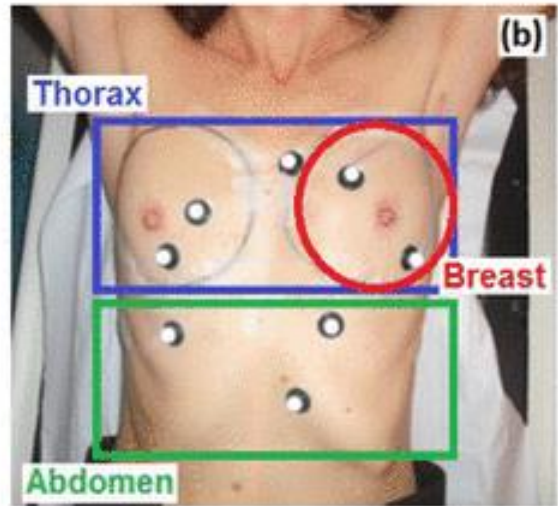


IGRT/ART – Organ Motion





(a)

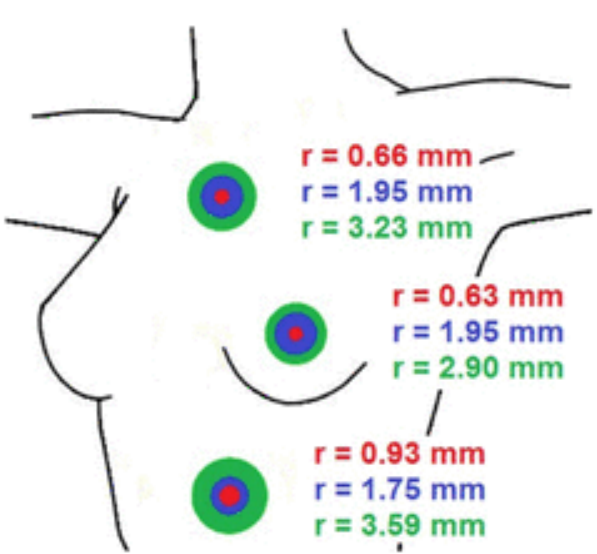


(b)

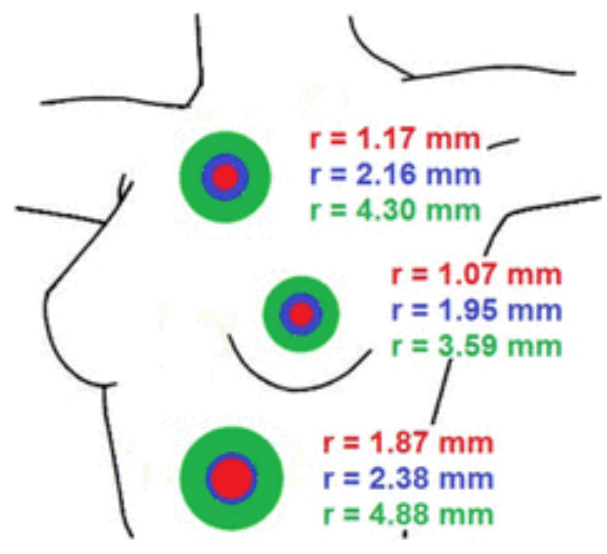


(c)

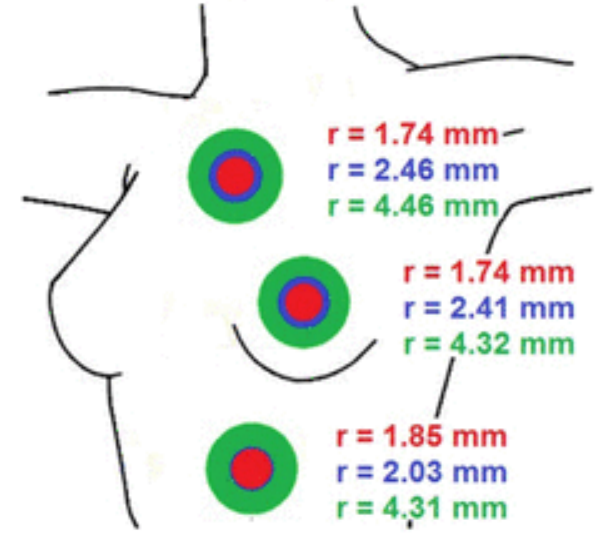
LL direction



AP direction

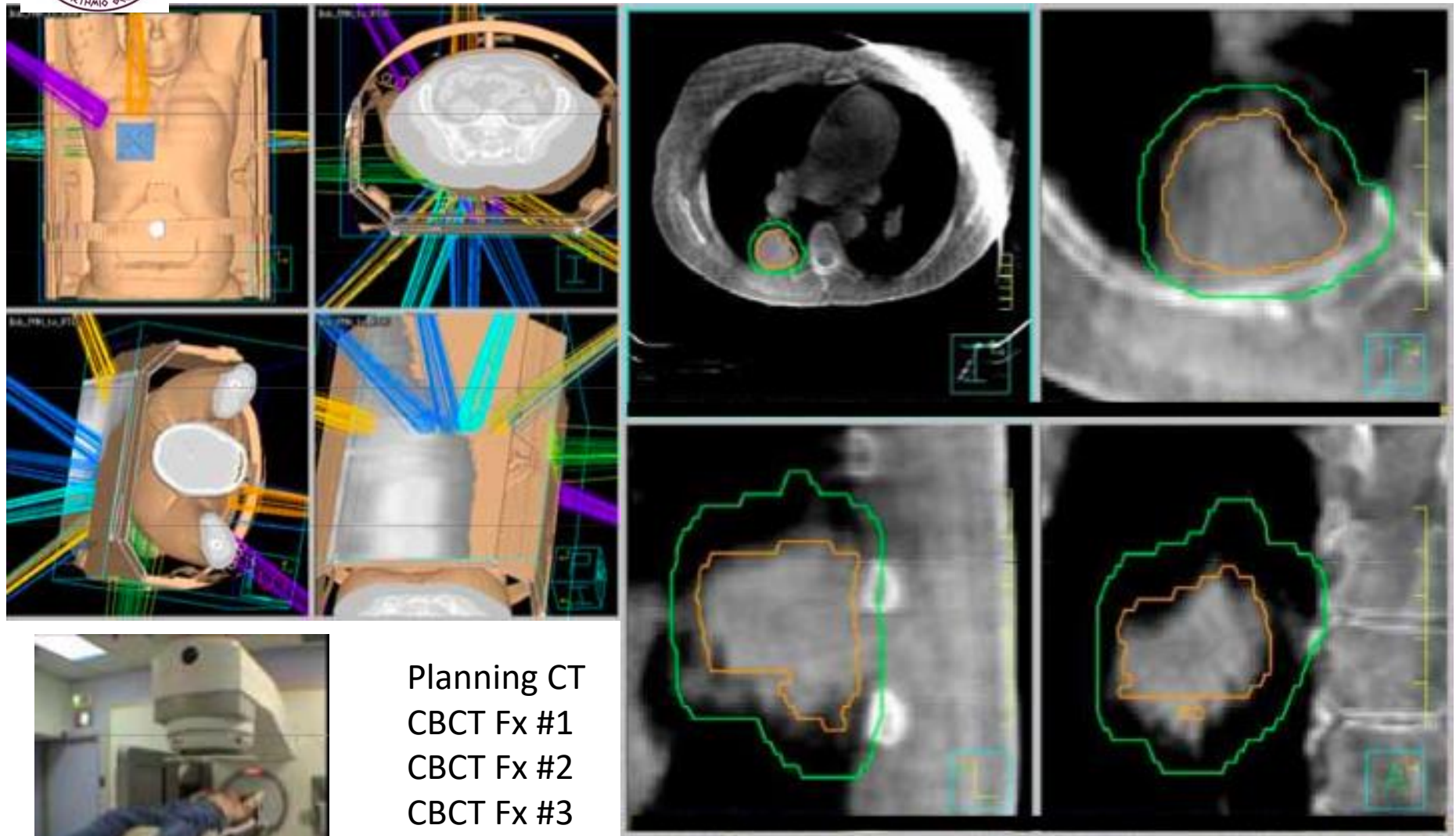


CC direction





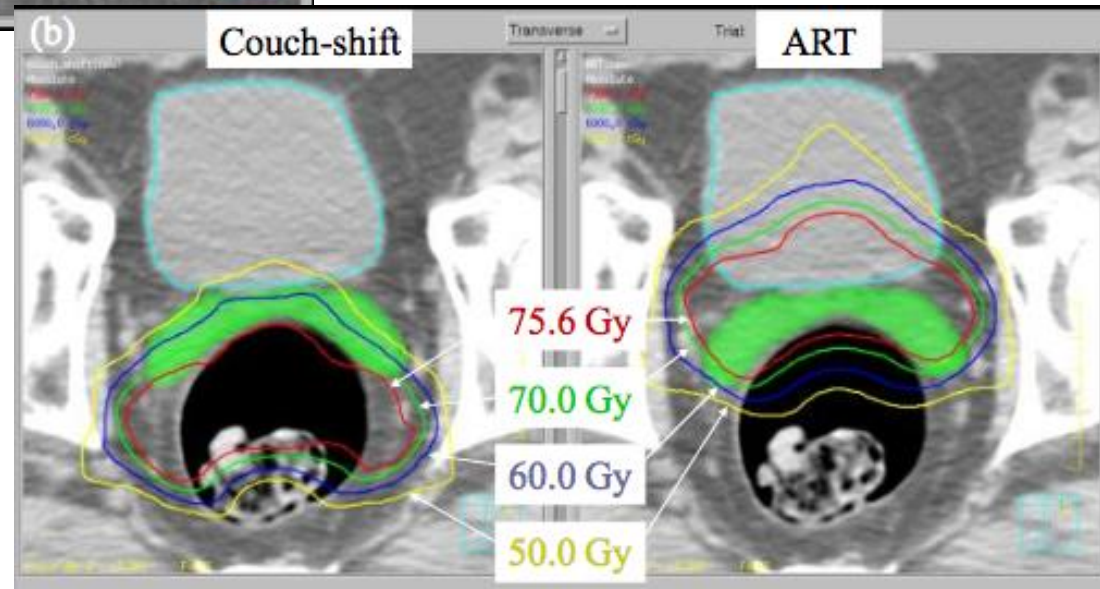
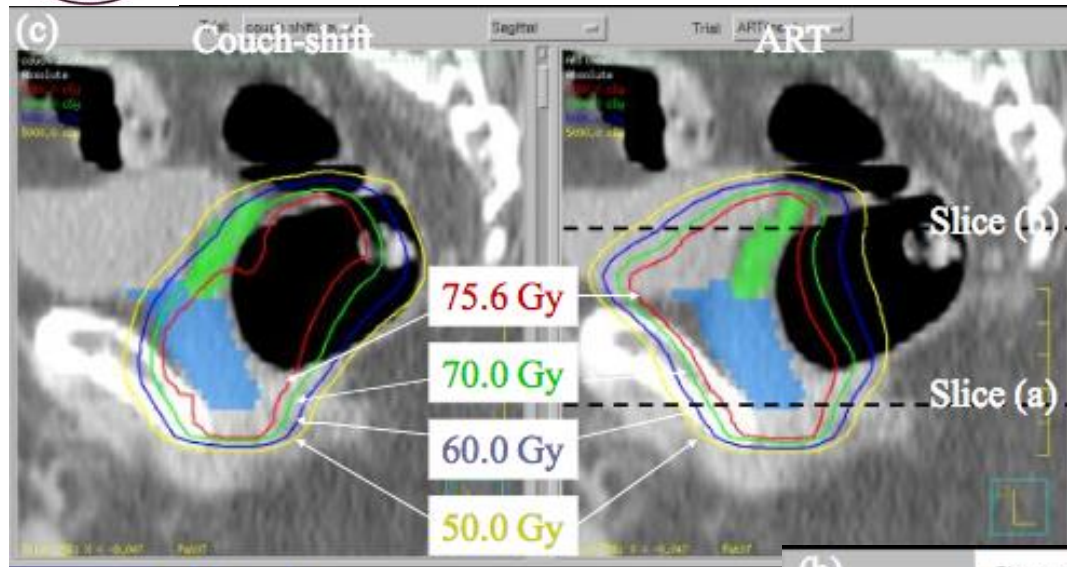
IGRT/Adaptive – 4D / Re-planning



Princess Margaret Hospital, Toronto, Canada

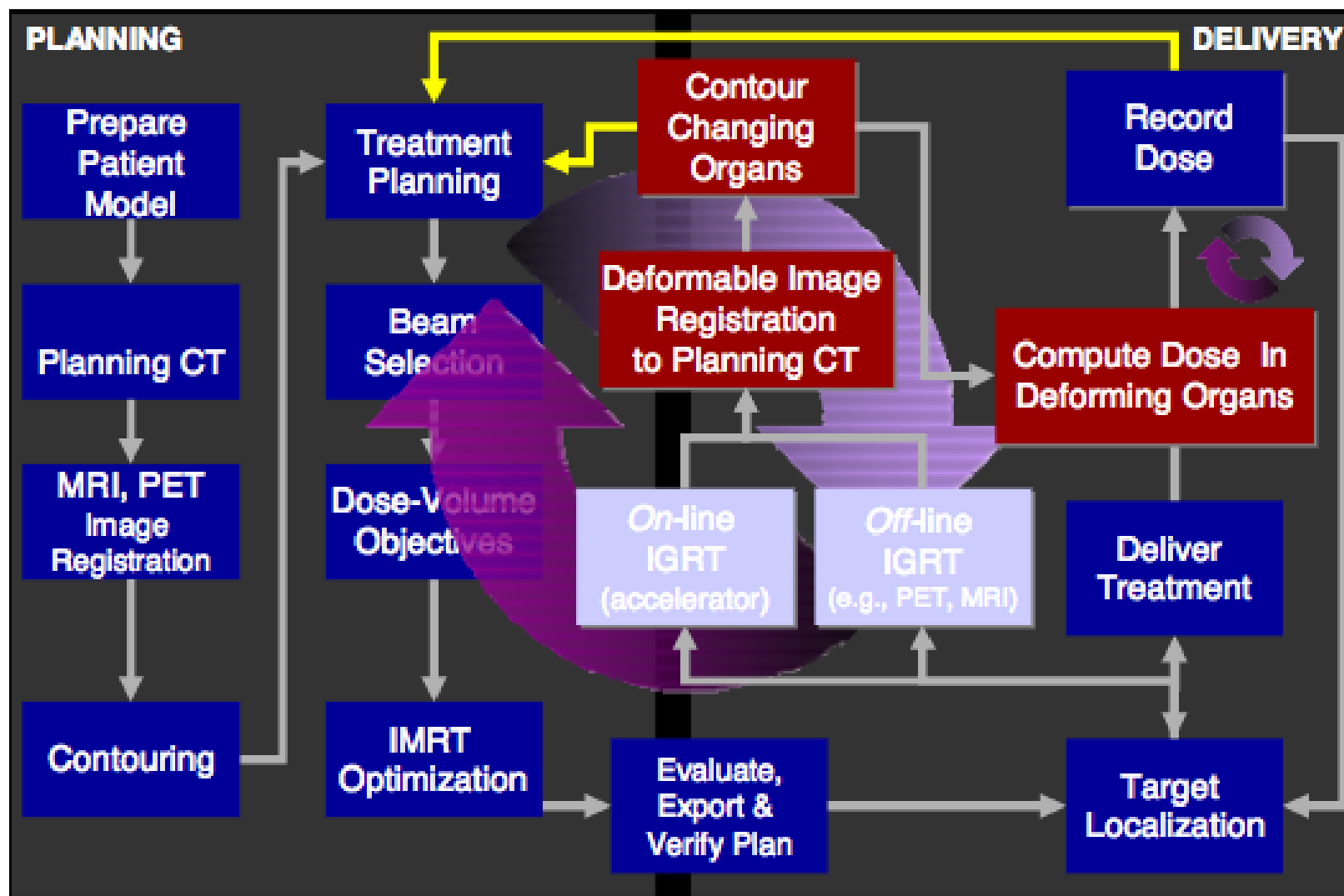


IGRT/Adaptive – 4D / Re-planning



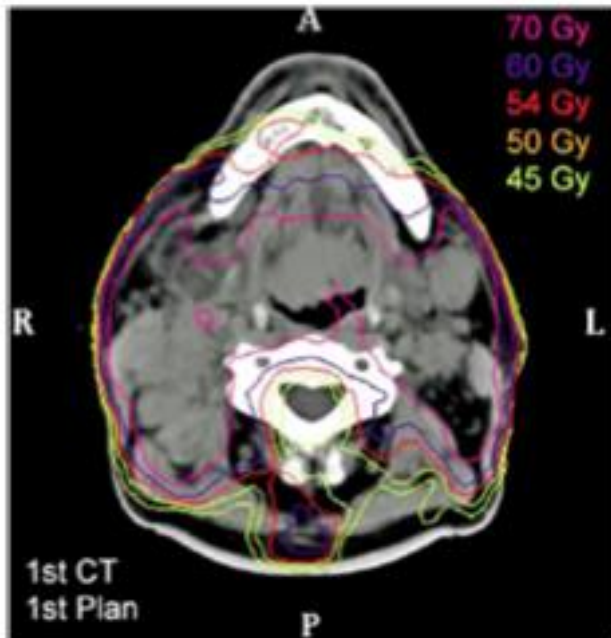


ART- Re-planning using DIR

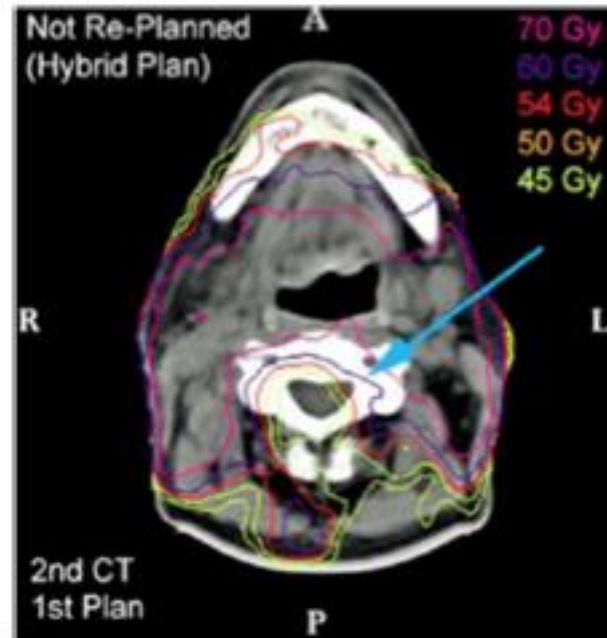




ART- Re-planning using DIR



Plan

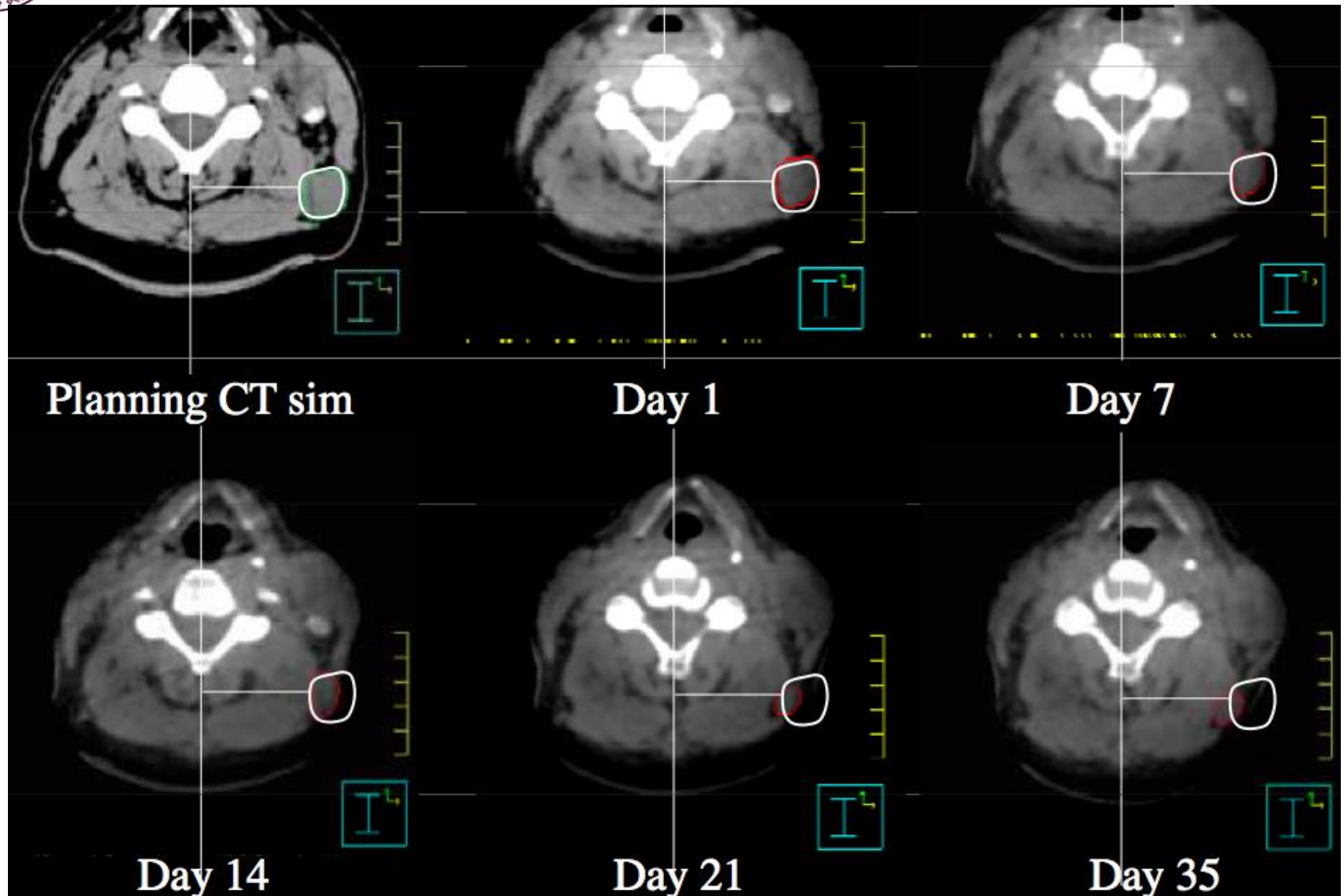


CT after 22 fx,
12 % weight loss

Hansen, IJROBP, 64, 355, 2006

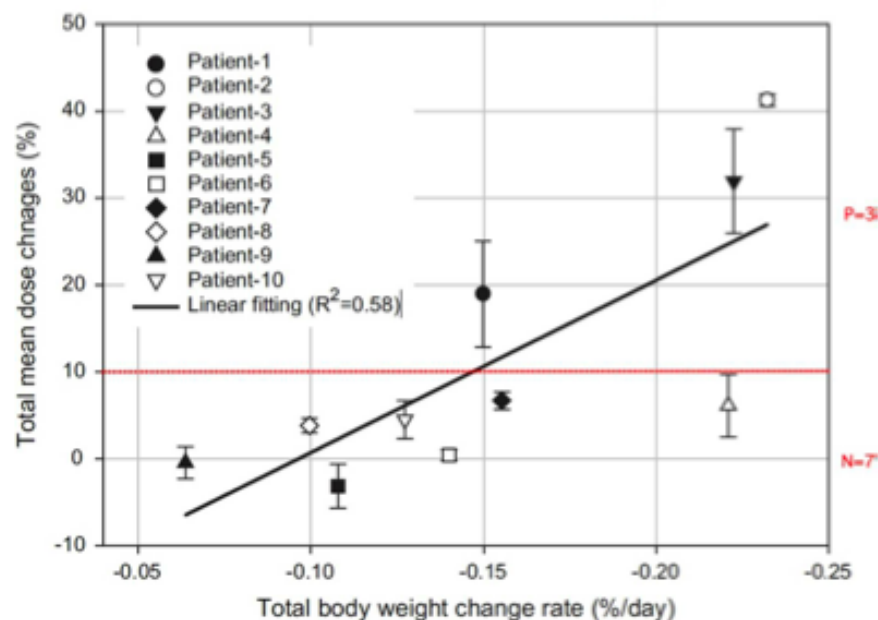
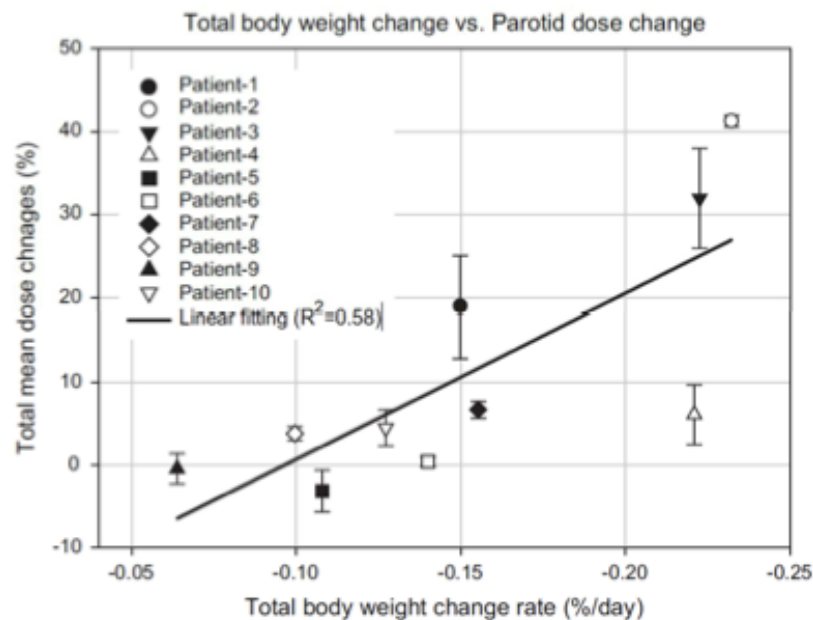


ART- Re-planning using DIR





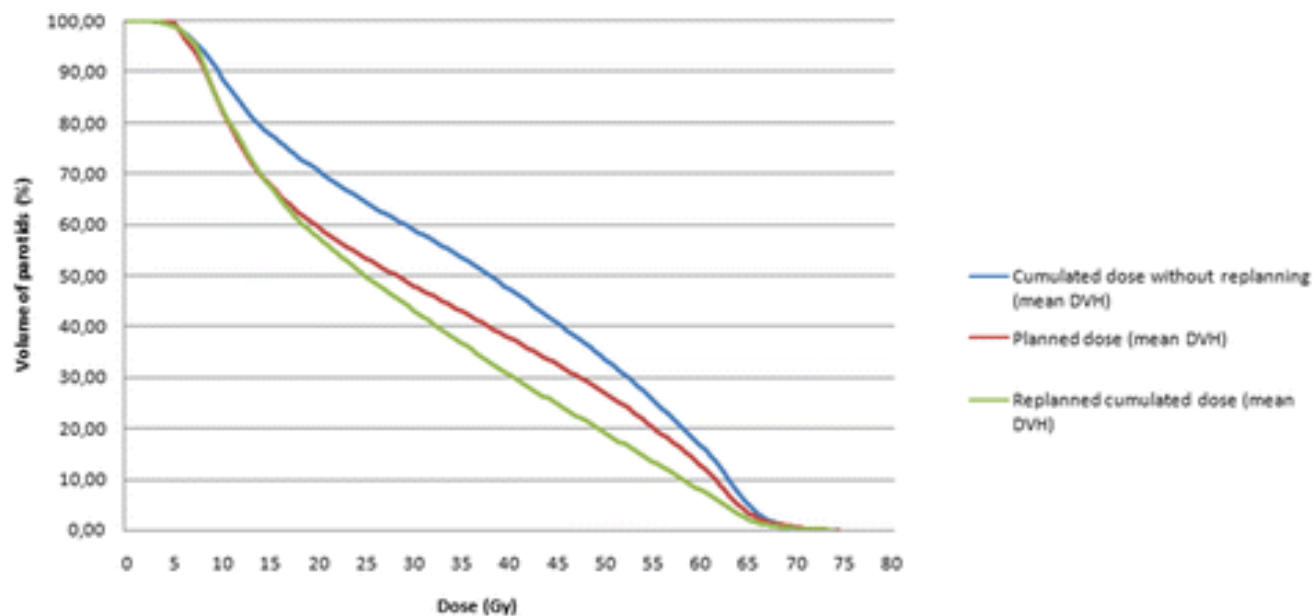
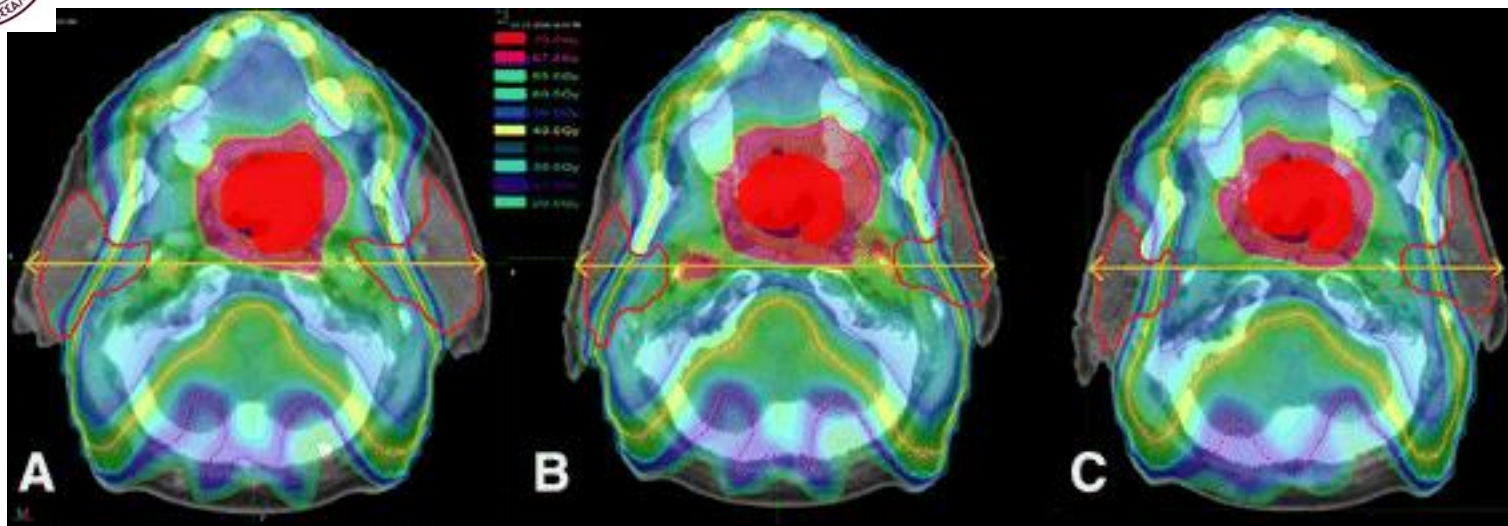
ART- Re-planning using DIR



Lee, IJROBP, 70, 1563, 2008

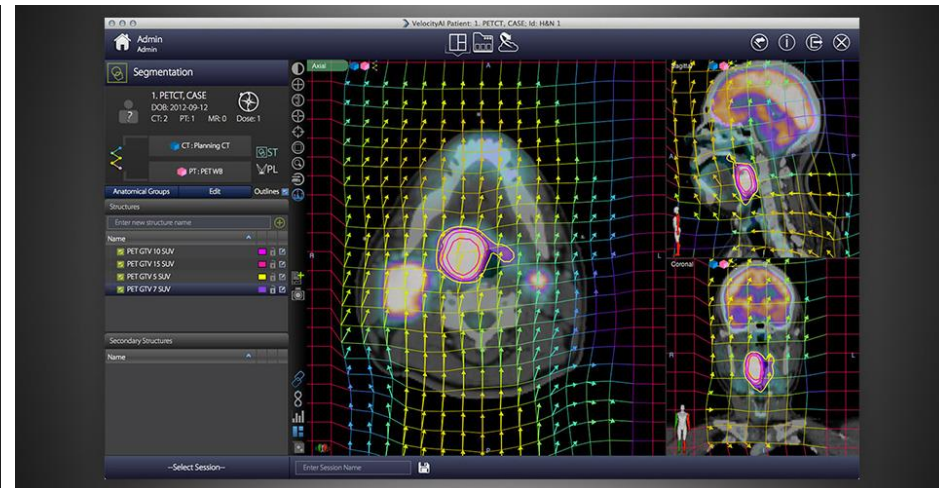
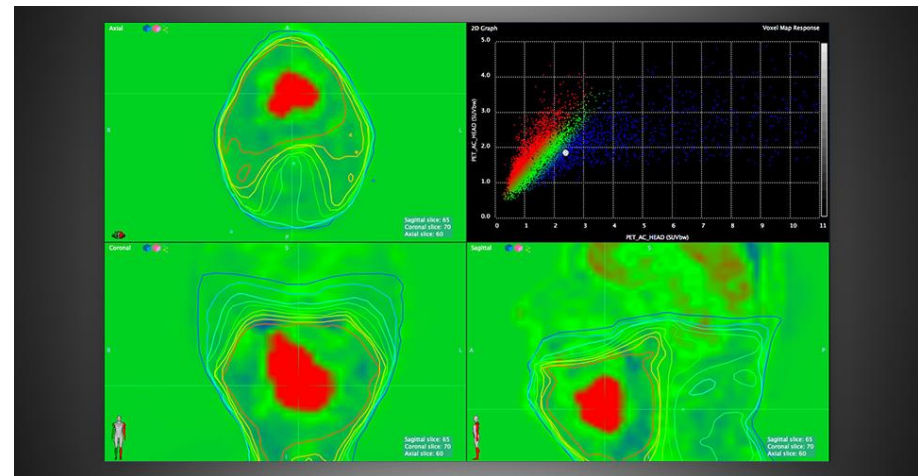


Adaptive Planning



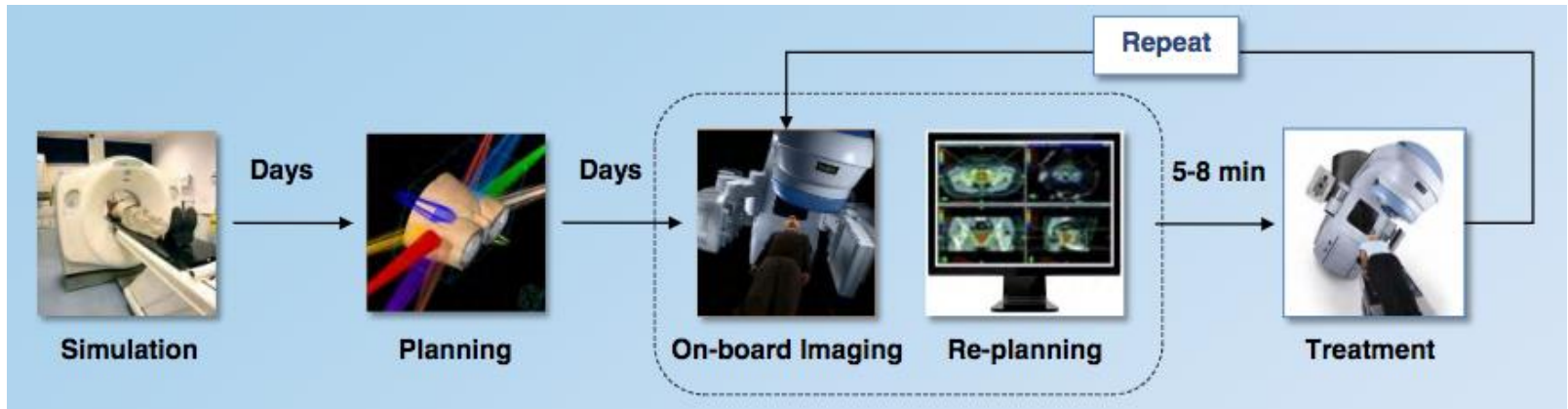


ART- Re-planning using DIR



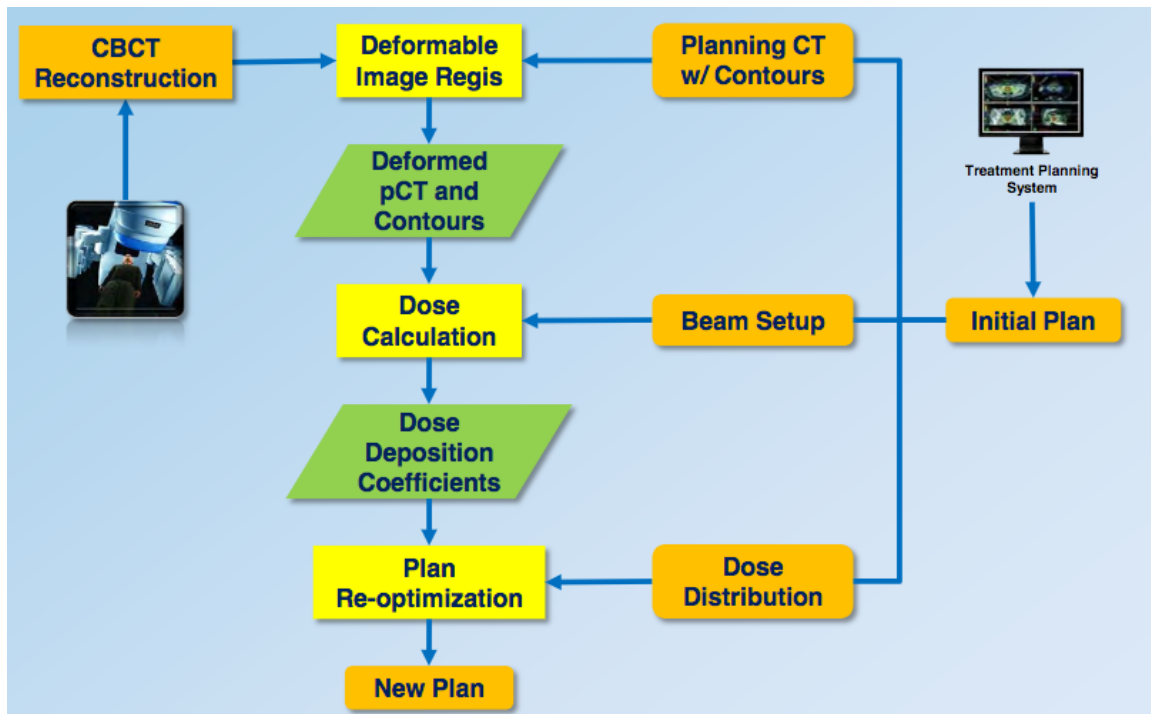


Online ART workflow



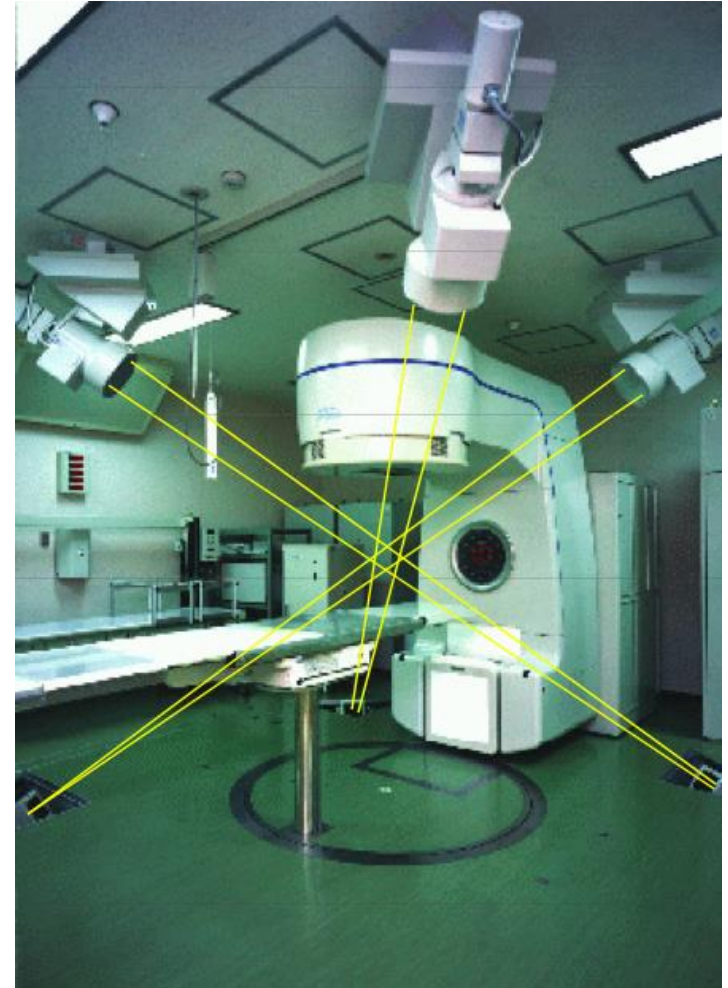
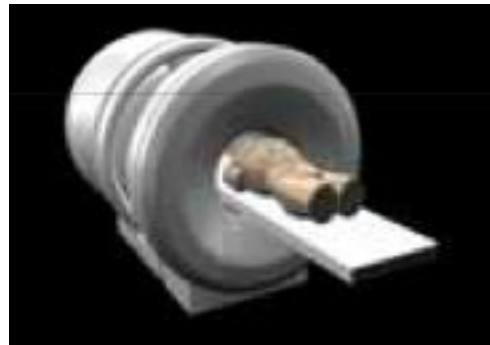
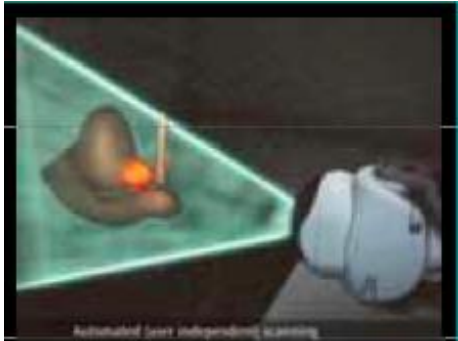
Considerations:

- Real-time planning
- Clinical workflow





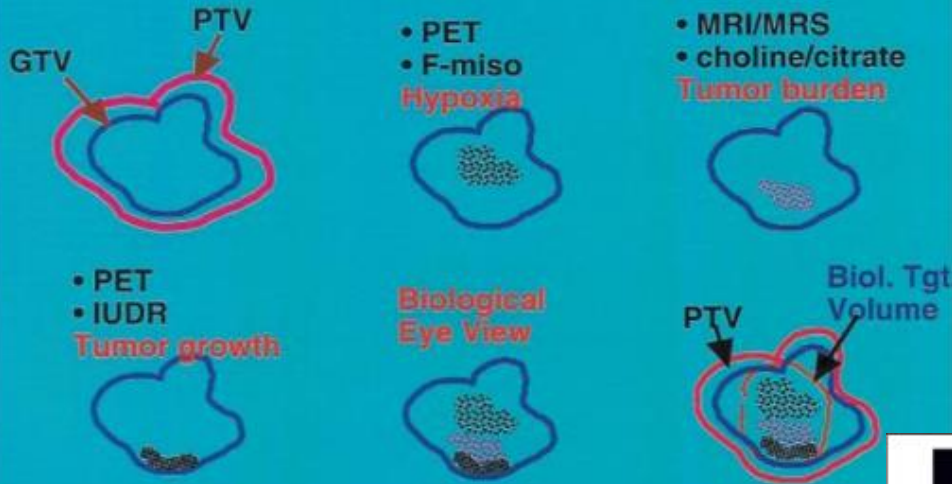
Online ART- Technology





Biological Target Volume

Biological Target Volume?

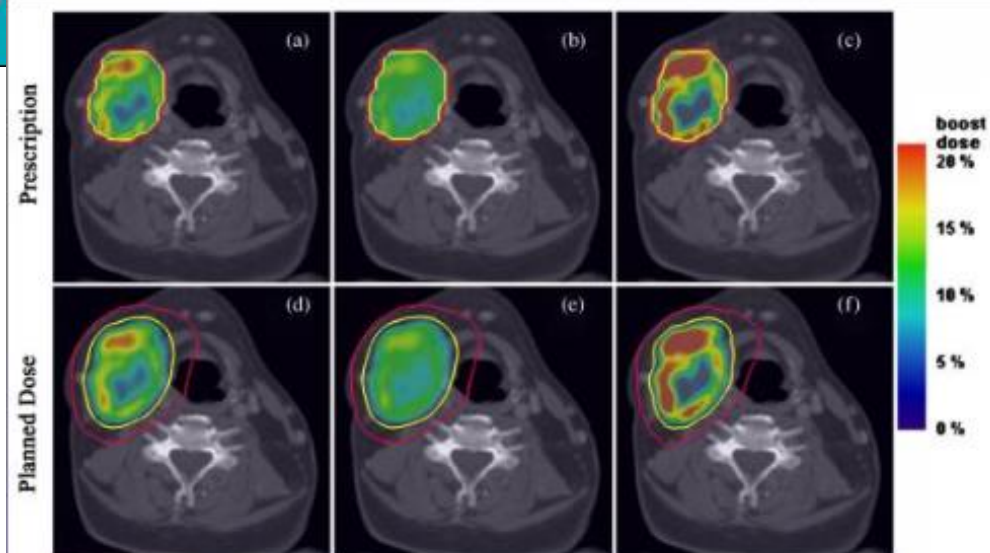


Bentzen (Lancet Oncol 2005)

- A partial GTV boost may be even more appealing if we can determine the parts of the GTV at the highest risk of failure because of high clonogen density, proliferation rate, hypoxic content, or low cellular radiosensitivity.

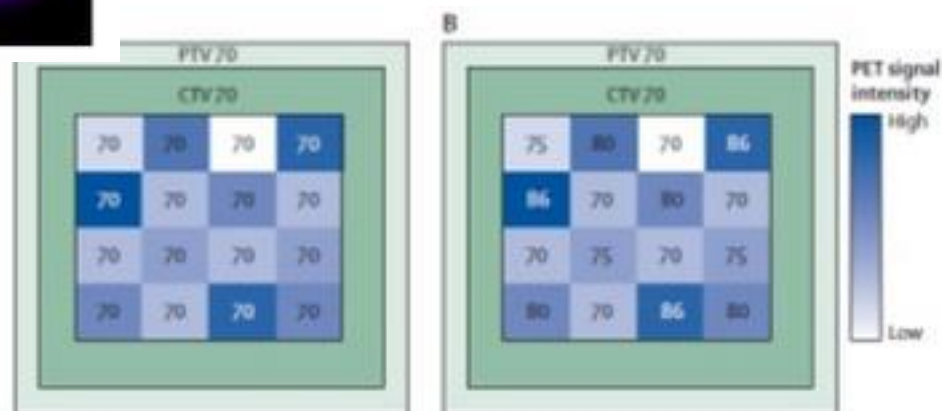
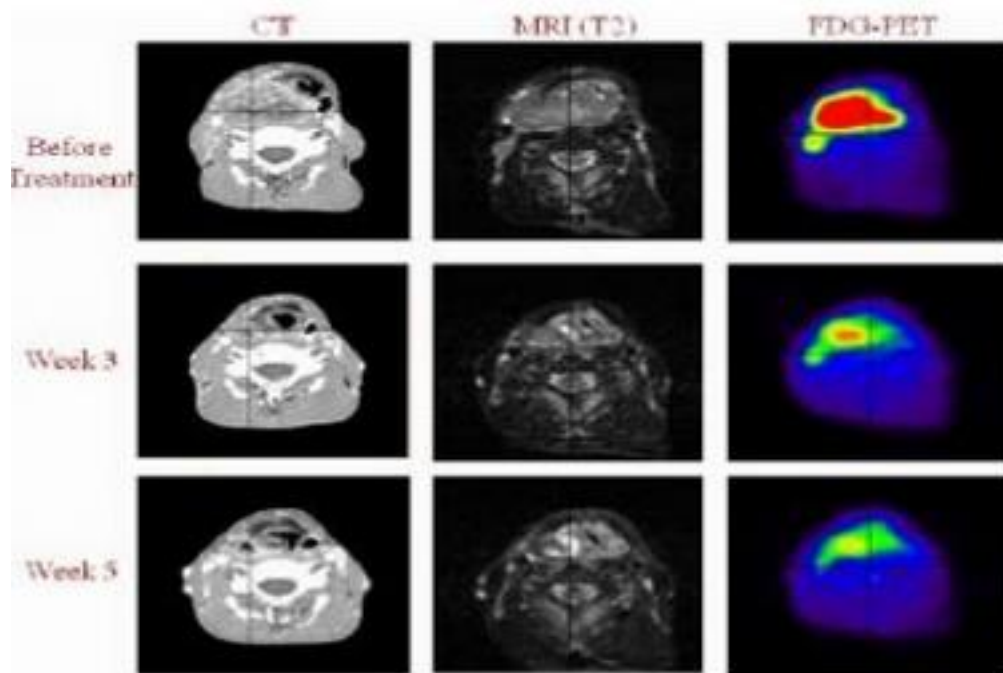
C. Ling et al. IJROBP Vol. 47 No. 3 p551, 2000

Brown SR et al. PMB 54 (2009) 1483-1501





Biological Target Volume – Dose Painting



Gregoire et al., Lancet Oncol 2012

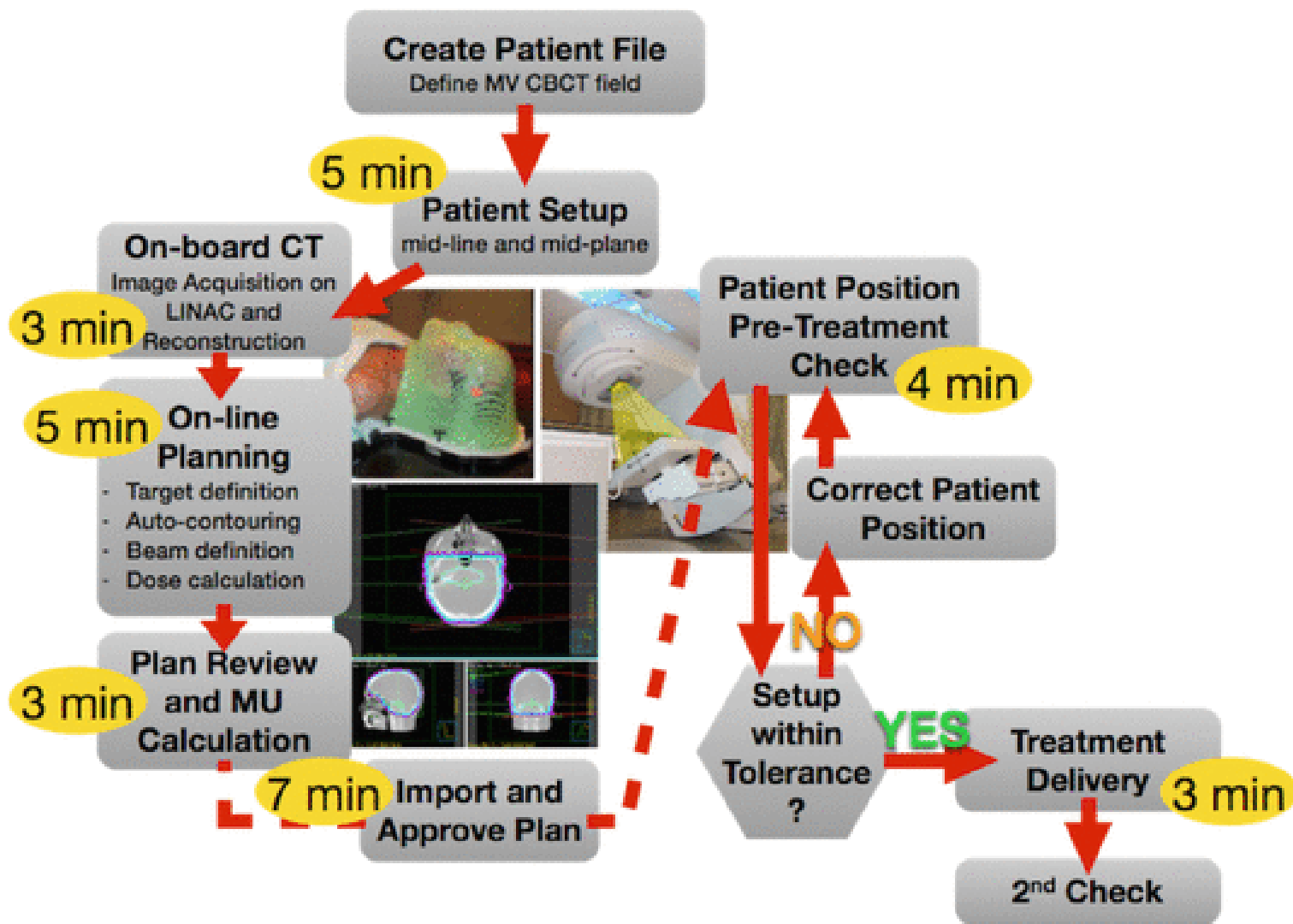


Can we be that accurate?

- Online target definition
- Online treatment adaptation
- Up-to-date treatment response information
- Further reduction on target volume
- Limitations of functional imaging



Everything has a cost...

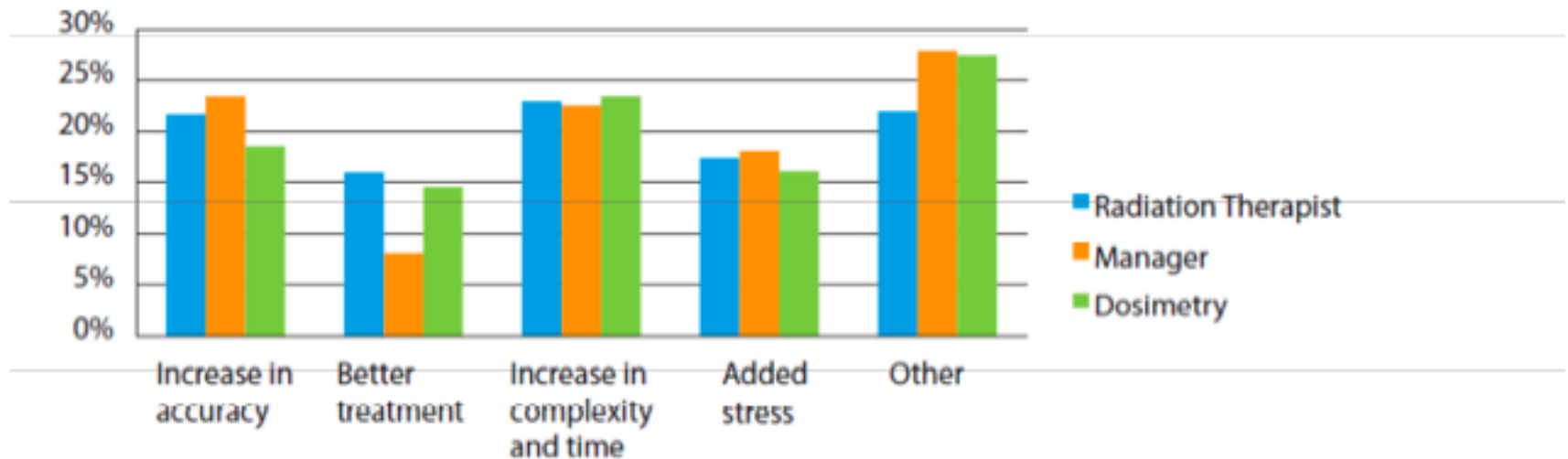


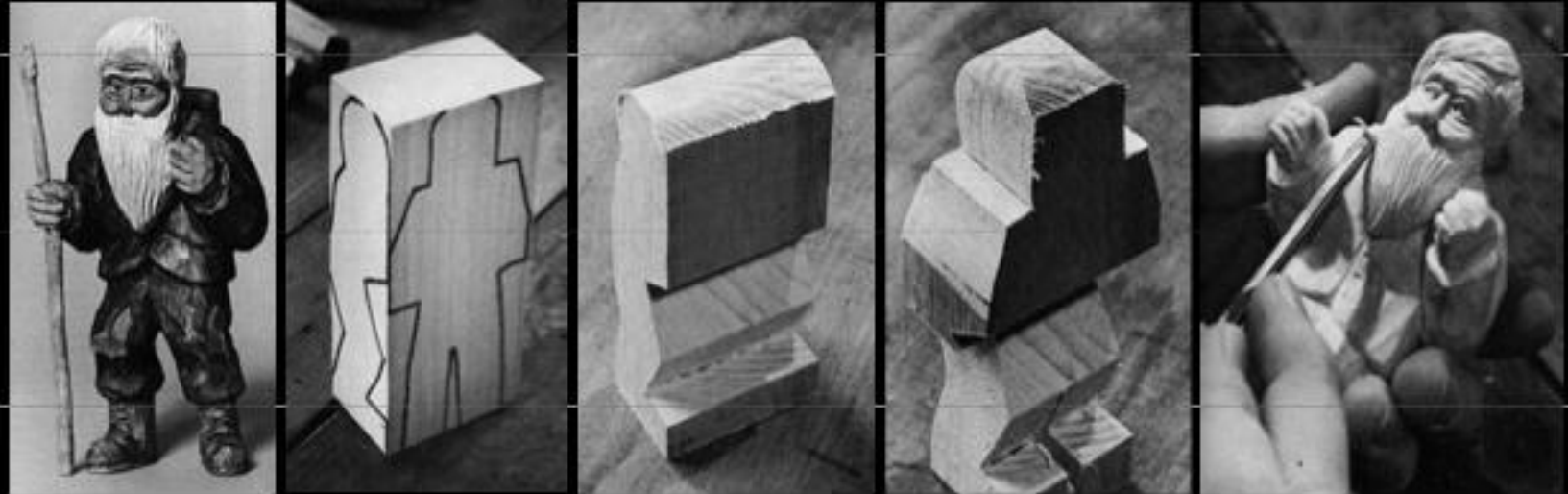


Everything has a cost...

Radiation Therapy, Management and Dosimetry Workplace Survey 2010

What other effects have technological developments had on your department over the past few years?
(Coded from verbatim responses.)





‘Actual’

IG-IMRT



Conclusions

- ✓ Personalized Adaptive Radiotherapy could increase the Radiotherapy efficiency
- ✓ Geometric and biological complexity could be addressed with the new systems
- Increase of complexity / small error margin
- Increase of attention and work load of the personnel
- Increase of time

WE ARE NOT THERE YET...



Practical Changes

- Time for imaging
- Time in Planning
 - Auto-segmentation
 - Correction strategies
 - Efficient re-planning
- Time for plan-verification (QA)
 - Approval process
 - Patient QA
 - R&V
- Adapting intra-fractional changes



Teşekkür Ederim