Online Adaptive Radiotherapy

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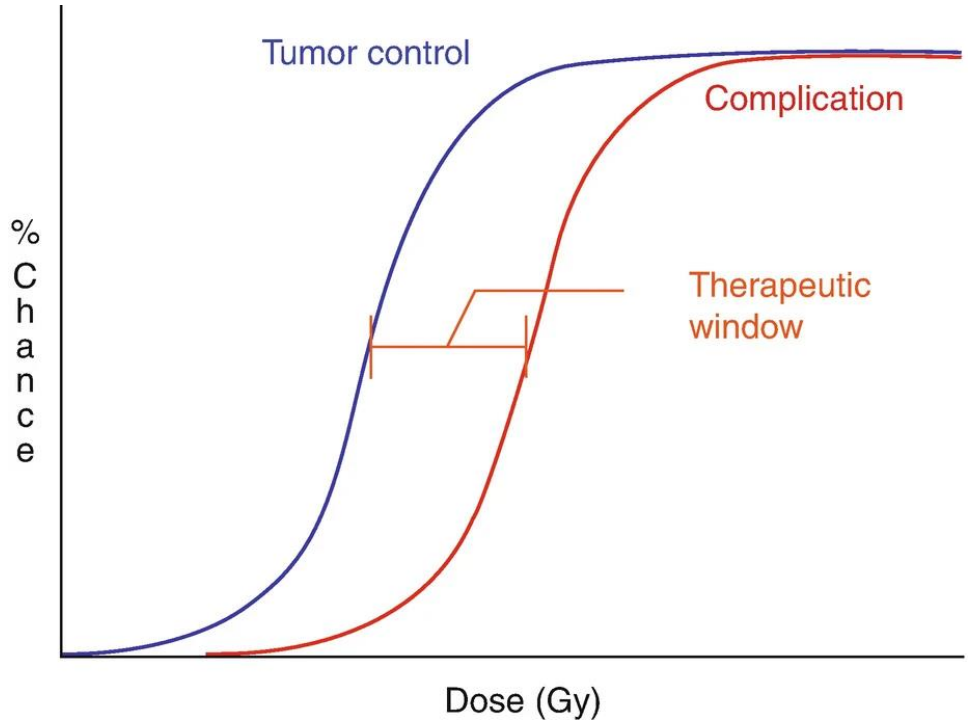
Background



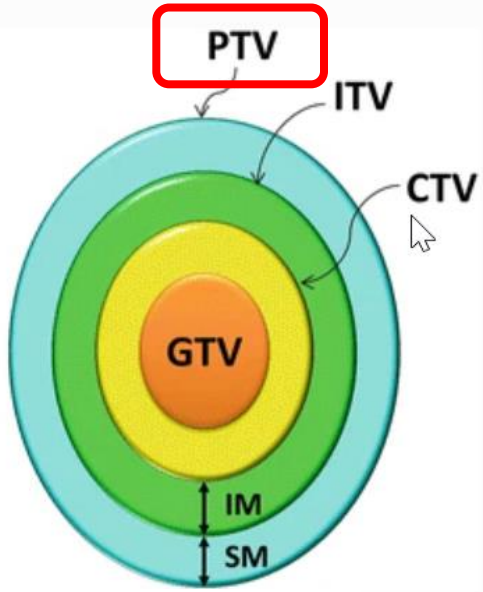
Basic Radiotherapy Physics and Biology pp 307–312

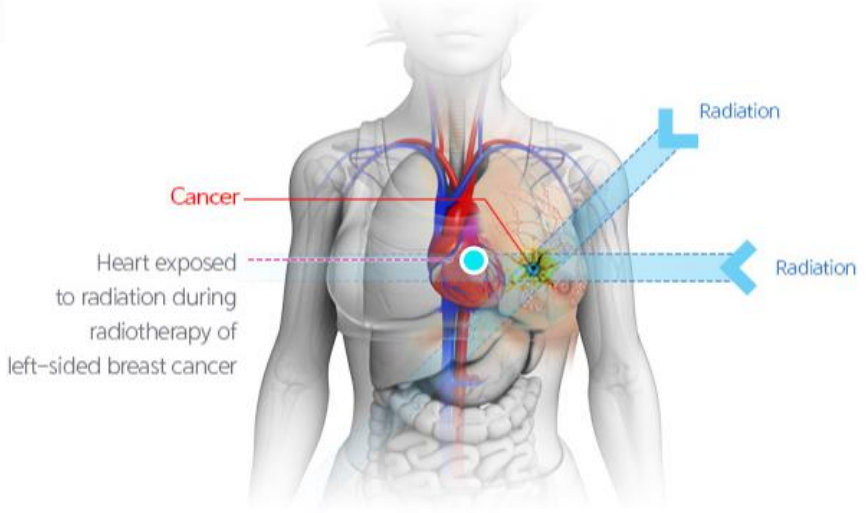
GTV: gross tumor volume, defined as visible tumor volume in images

CTV: clinical target volume, defined as GTV + subclinical/invisible invasion

ITV: internal target volume, defined as CTV + IM (internal margin for organ motion)

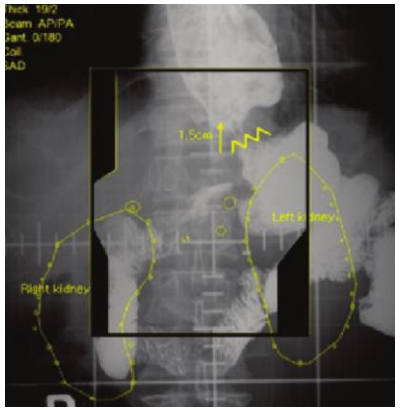
PTV: planning target volume, defined as ITV + SM (setup margin for setup error)

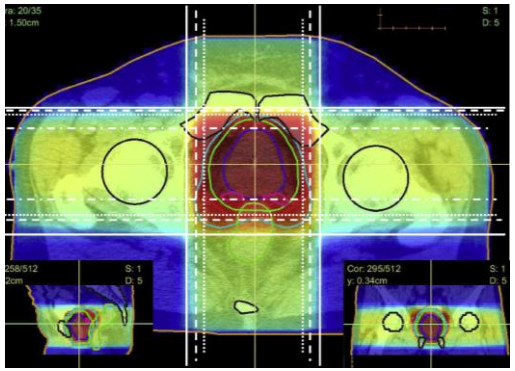


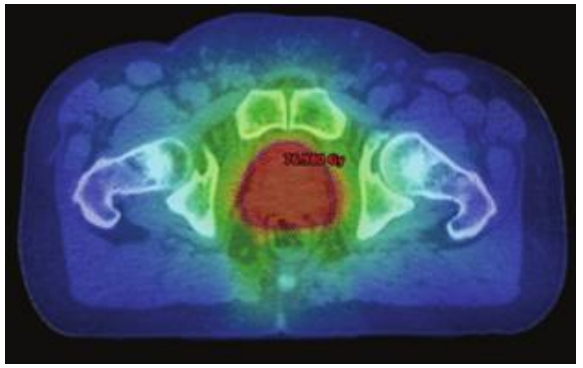


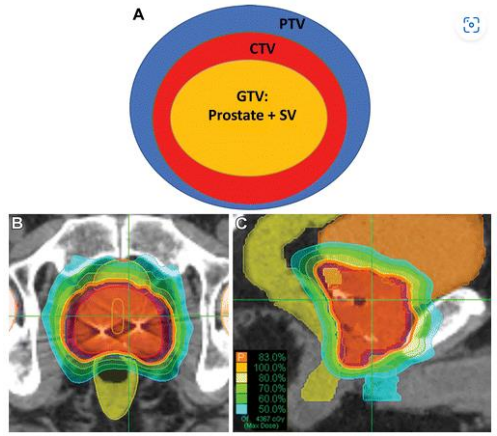
Ideal world: 100% of radiation dose to PTV and 0% to OARS!

Background







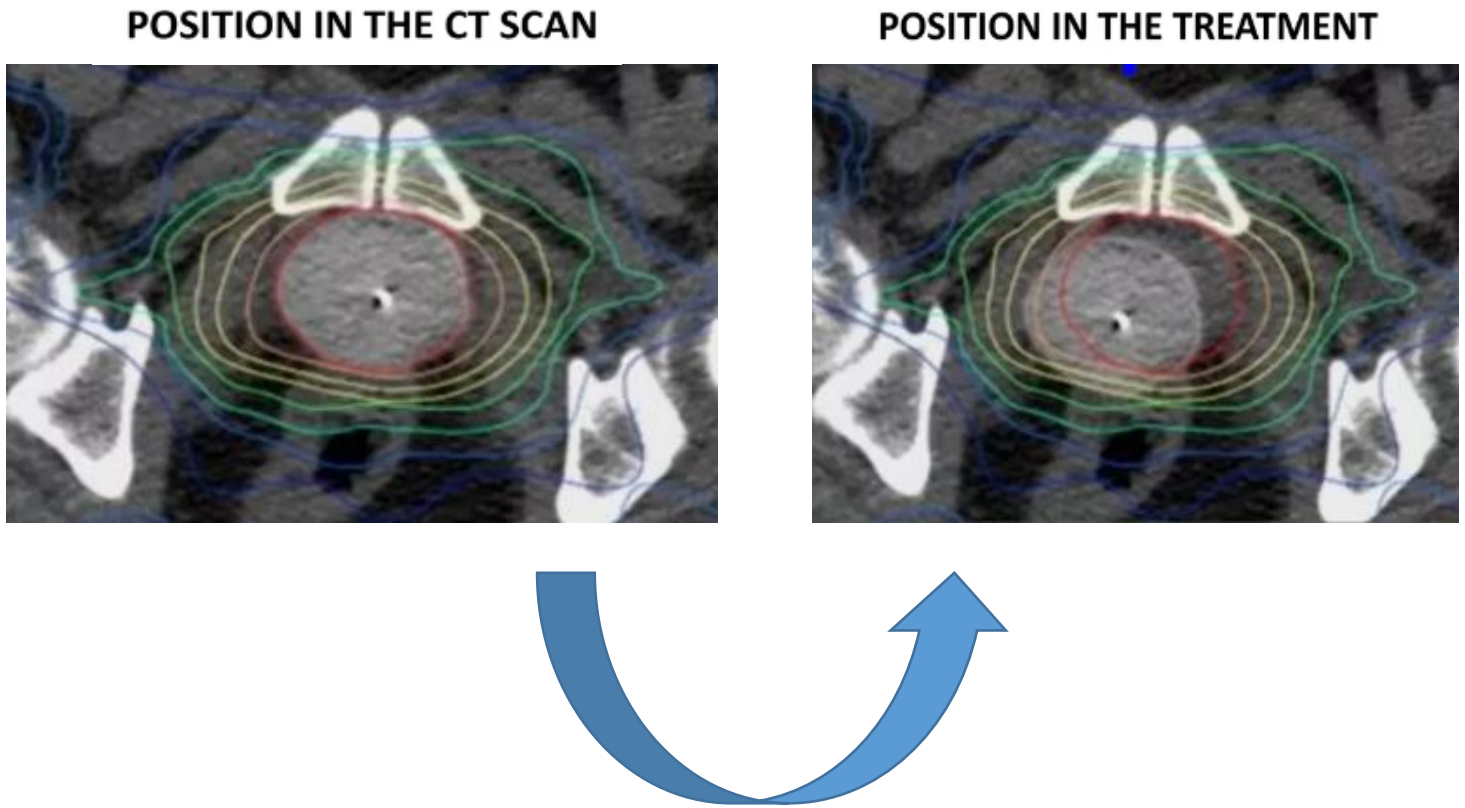


2D-RT 3D-CRT VMAT SBRT

Significant improvement in RT techniques!

Is that enough?

Background



Main reasons:

- Mispositionning
- Organ motion
- Change of shape

Is correction always possible with image-guidance???

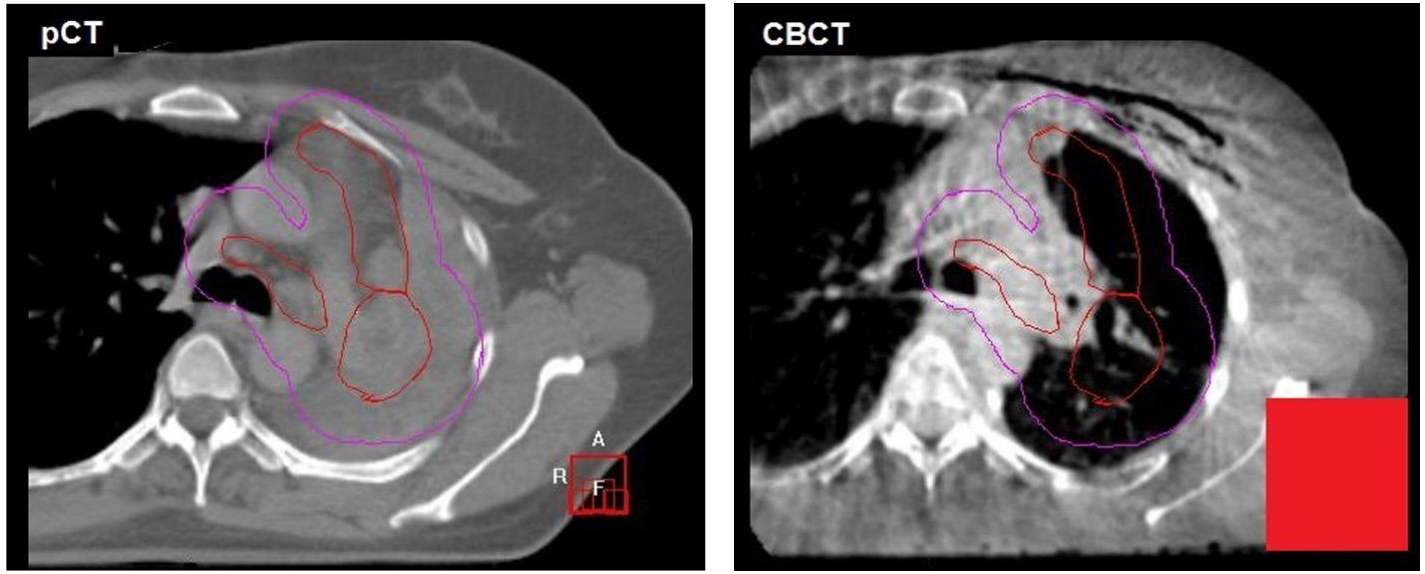
Background

- Anatomical changes during the course of cancer treatment

PTV

GTV

M. Kwint et al. / Radiotherapy and Oncology 113 (2014) 392–397



- cT4N2M0 NSCLC
- RT: 24 x 2.75Gy
- Initial atelectasis of left lung
- CBCT of week 3

High risk of tumor undercoverage!

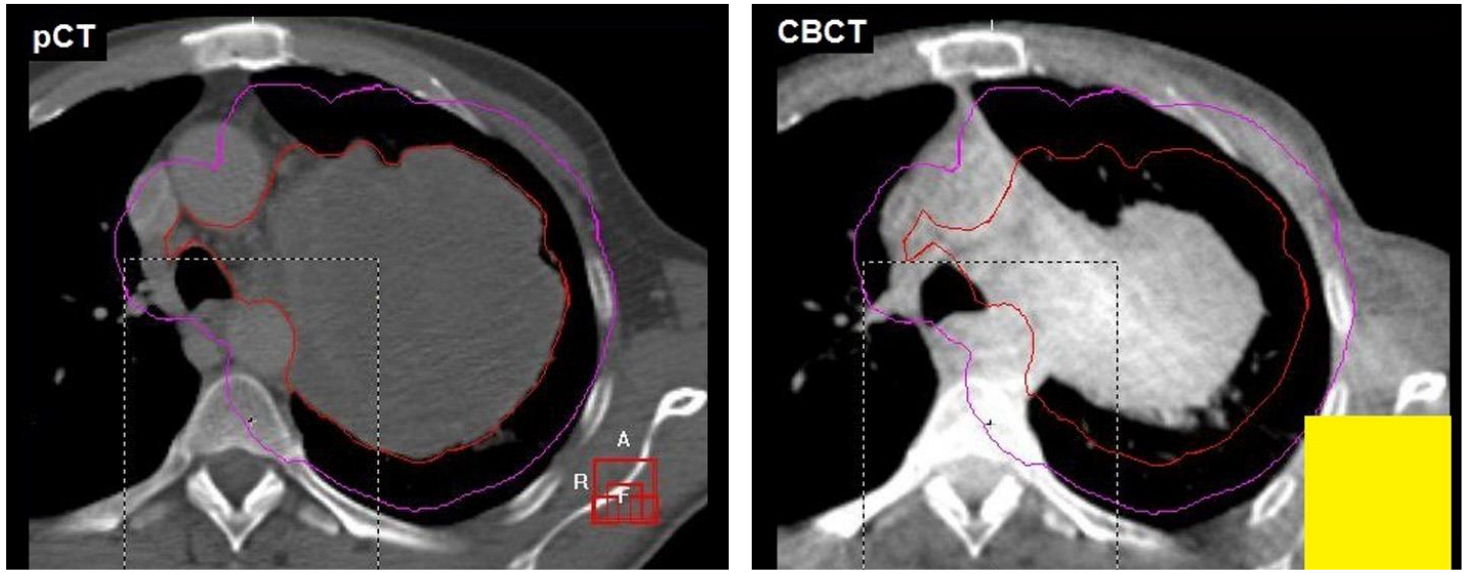
Background

- Tumor shrinkage during the course of cancer treatment

PTV

GTV

M. Kwint et al. / Radiotherapy and Oncology 113 (2014) 392–397



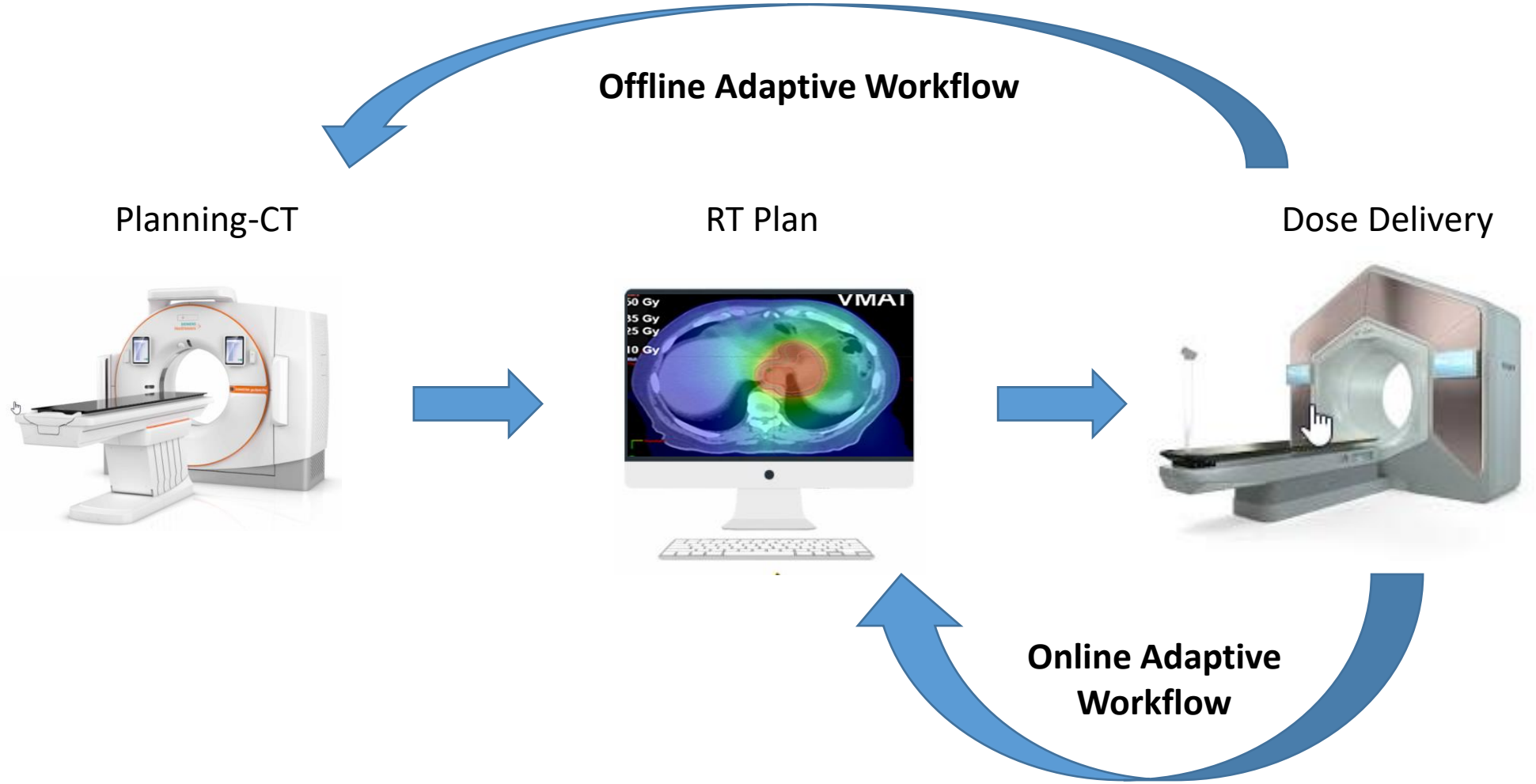
- cT4N2M0 NSCLC
- RT: 17 x 3Gy
- CBCT of week 3

High risk of lung toxicity!

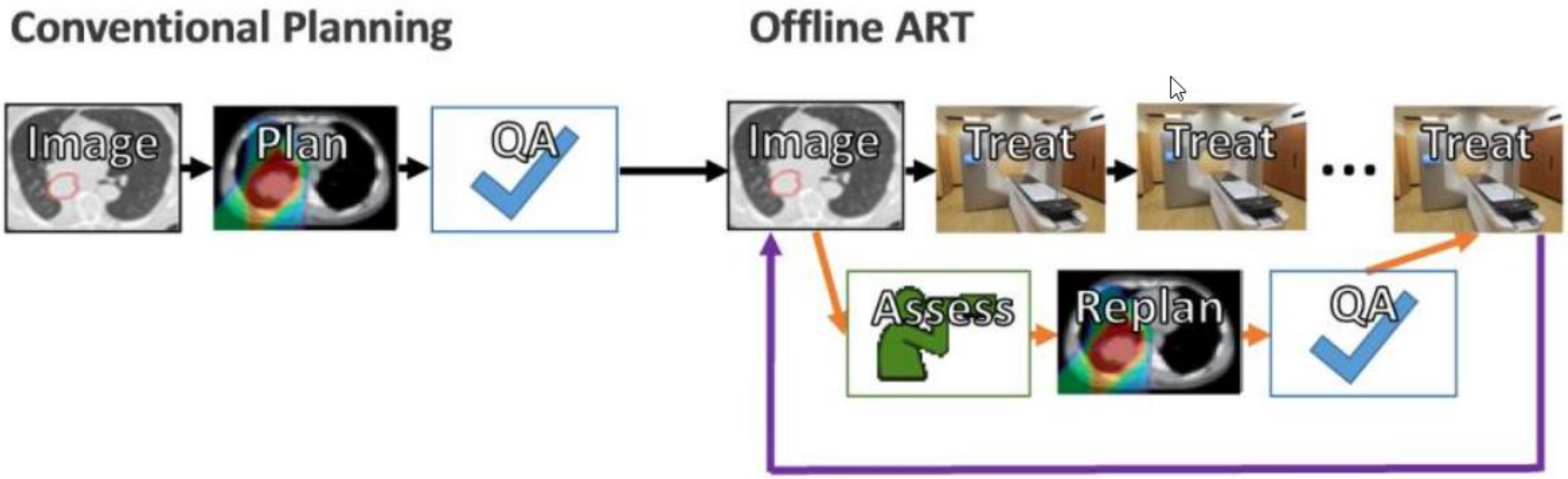
Adaptive Radiotherapy (definition)

Changing the RT plan (re-planning) in reaction to geometrical/anatomical changes in the patient!

Adaptive Radiotherapy



Adaptive Radiotherapy (offline)



Daily CBCT evaluation of anatomical changes and re-planning when necessary!

Adaptive Radiotherapy (offline)

Review Article

Adaptive Radiation Therapy for Head and Neck Cancer—Can an Old Goal Evolve into a New Standard?

David L. Schwartz[1] and Lei Dong[2]

[1] *Department of Radiation Medicine, North Shore-LIJ Health System, 270-05 76th Avenue, New Hyde Park, NY 11040, USA*
[2] *Department of Radiation Physics, University of Texas MD Anderson Cancer Center, Unit 94, 1515 Holcombe Blvd., Houston, TX 77030, USA*

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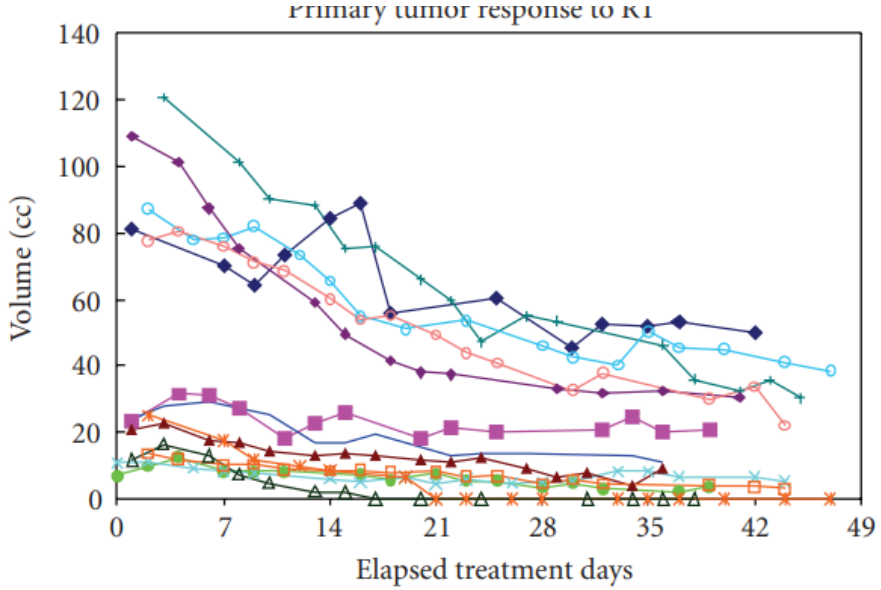
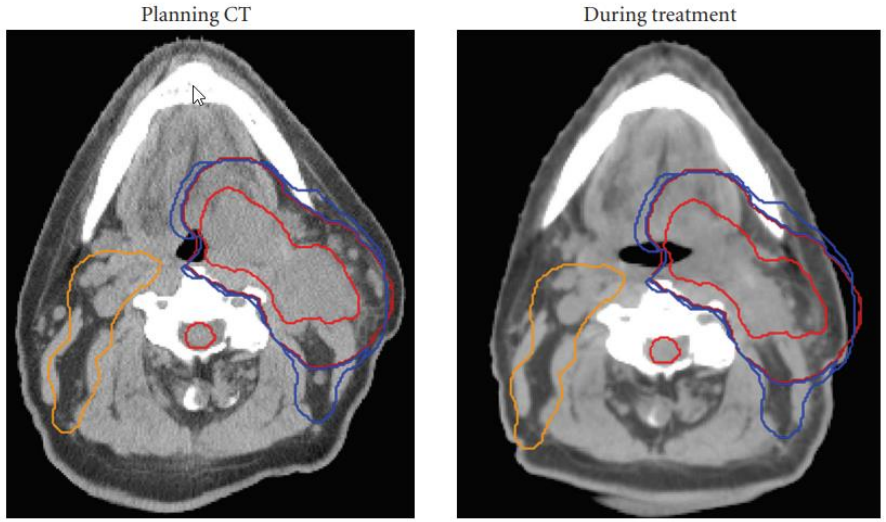
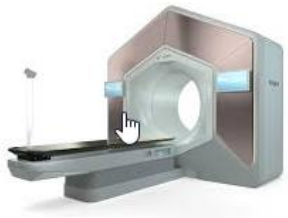
Received 8 April 2010; Accepted 21 June 2010





Adaptive Radiotherapy (online)



Acquisition of planning-CT scan

Fusion of planning-CT and diagnostic images

Target and OAR delineation

Creation of reference treatment plan

Acquisition of daily CBCT

Check/adjust the contours for influencers

Check/adjust the contours for target volumes

Compare scheduled with adaptive plan

Plan selection (mostly the adaptive)

Online QA for adaptive plan (Mobius)

CBCT and shift before dose delivery

Dose delivery

Repeat every day (20-25min)

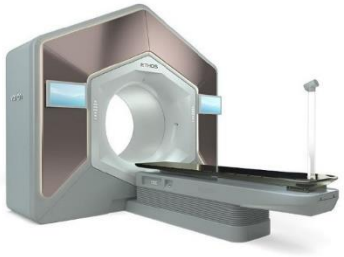
Adaptive Radiotherapy (Inselspital)

19.07.2021 Go-live
1st patient with esophageal cancer (IGRT)

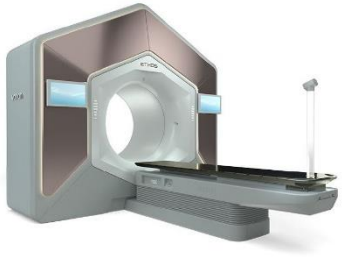
IGRT: Esophageal cancer, rectal cancer, anal cancer, prostate cancer, palliative RT

10.01.2022 Go-live
1st patient with esophageal cancer (ART)

Ethos vs. Truebeam



Treatment planning system	Ethos	Eclipse
Dose calculation algorithm	Acuros XB	AAA (Standard) Acuros XB EMC (Electrons)
IGRT	Daily kV-CBCT mandatory	kV/MV planar kV-CBCT
6D-Couch	No	Yes



Online-ART	Yes	No
Treatment technique 3DCRT Gating IMRT VMAT	 No No Yes Yes	 Yes Yes Yes Yes
Beam direction	coplanar only	coplanar non-coplanar
Jaws	No	Yes
MLC	Dual layer MLC	Single layer MLC (MLC120)
Max. Field Size	28 x 38.5 cm^2	40 x 40 cm^2
Particles	Photons	Photons, Electrons
Energies	6 MV	4 – 15 MV (Photons) 6 – 22 MeV (Electrons)
Flattening Filter	FFF	FF (Standard) FFF
Dose Rate	800 MU/min	up to 2400 MU/min

ETHOS: Limitations

- Electron plans: e.g. superficial tumors, Mamma boost
- IGRT plans: Where 6DOF couch is required (H&N, stereotactic radiotherapy)
- 3D (non-modulated) plans
- Gating
- Large volumes in longitudinal direction
- Situations where non-coplanar beam directions are beneficial (e.g. intracranial, radiosurgery)
- Situations where higher photon energies are beneficial (large patients)
- Presence of implants: Truebeam workflow maybe more efficient

Adaptive Radiotherapy

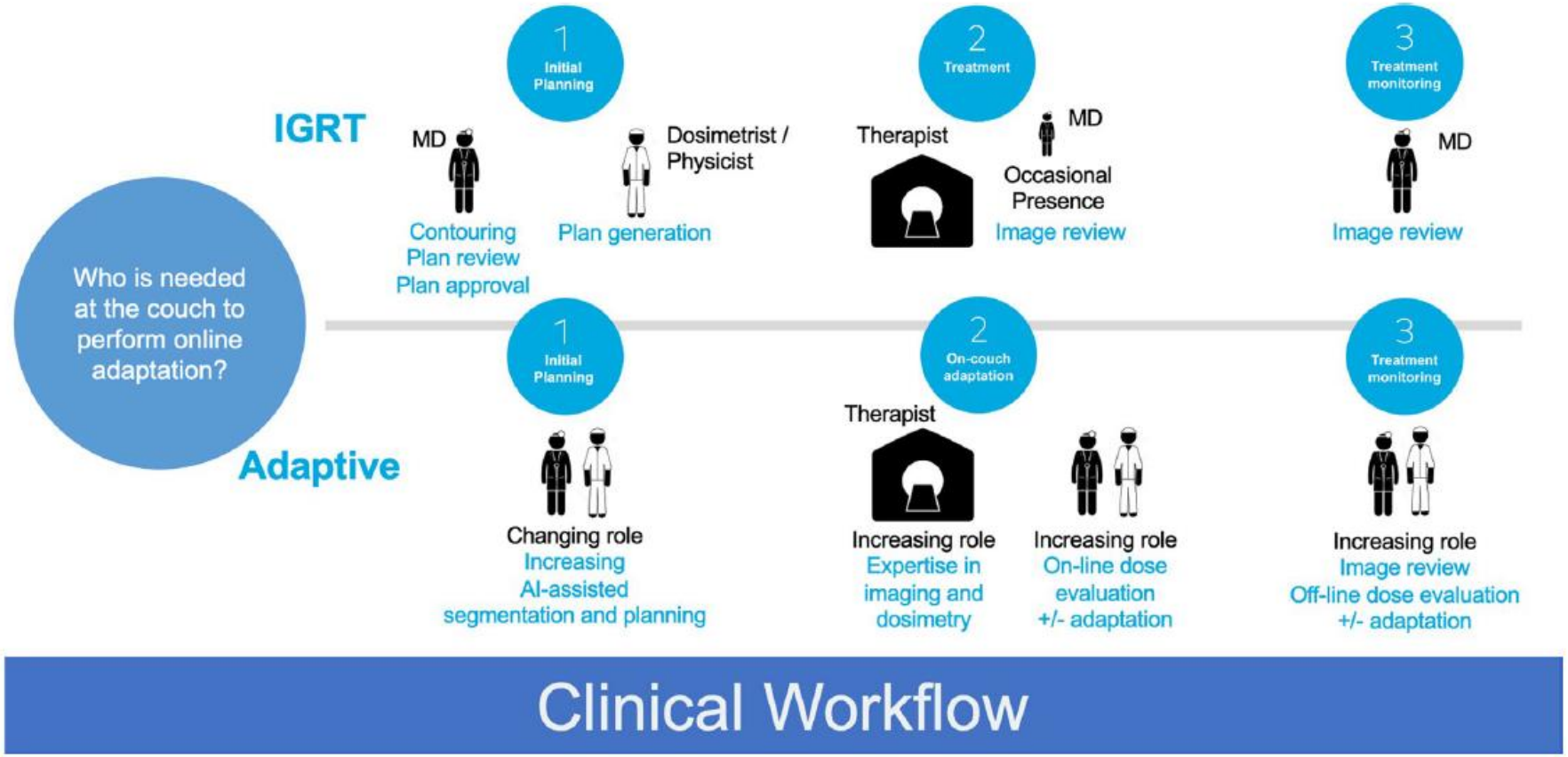
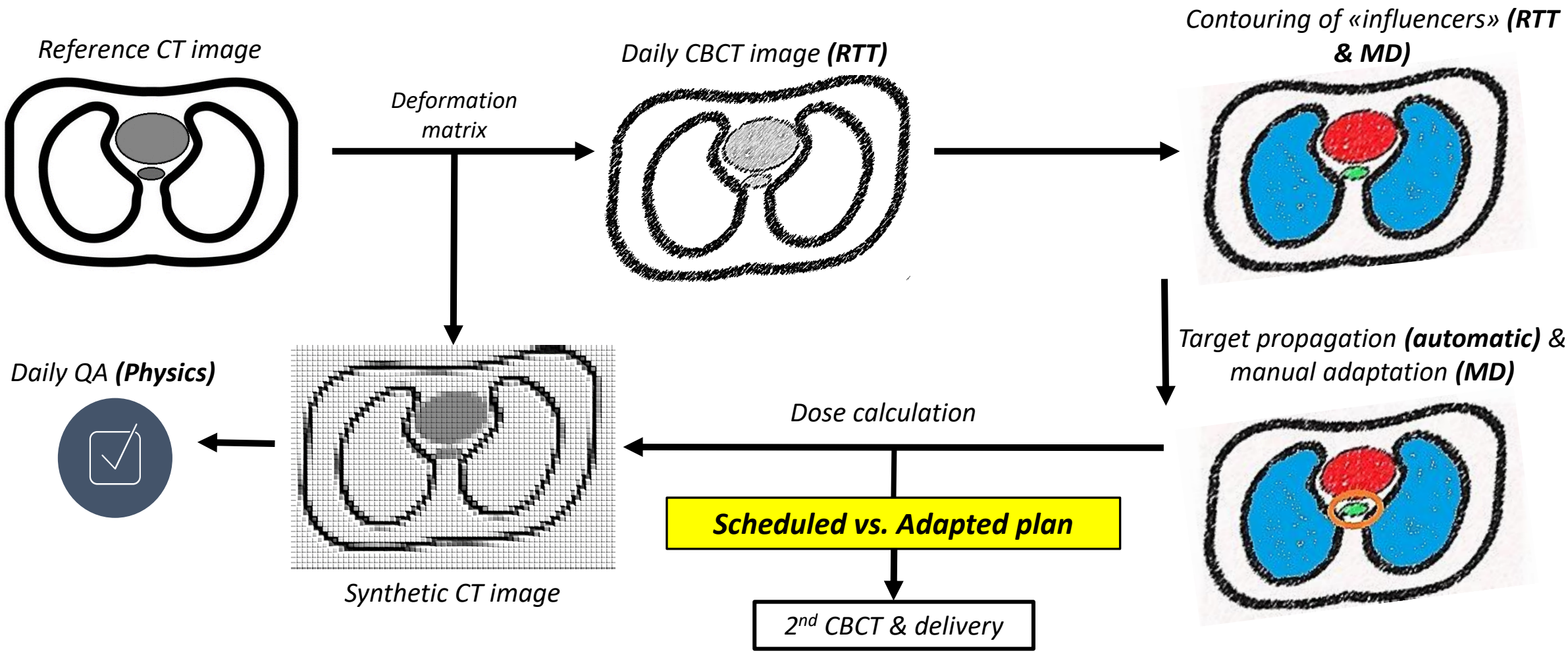


Fig. 2 Workflow comparison between IGRT and adaptive radiotherapy

Liu *et al. Radiation Oncology* (2023) 18:144

ART: Resources, Time, Expertise!

Adaptive Radiotherapy



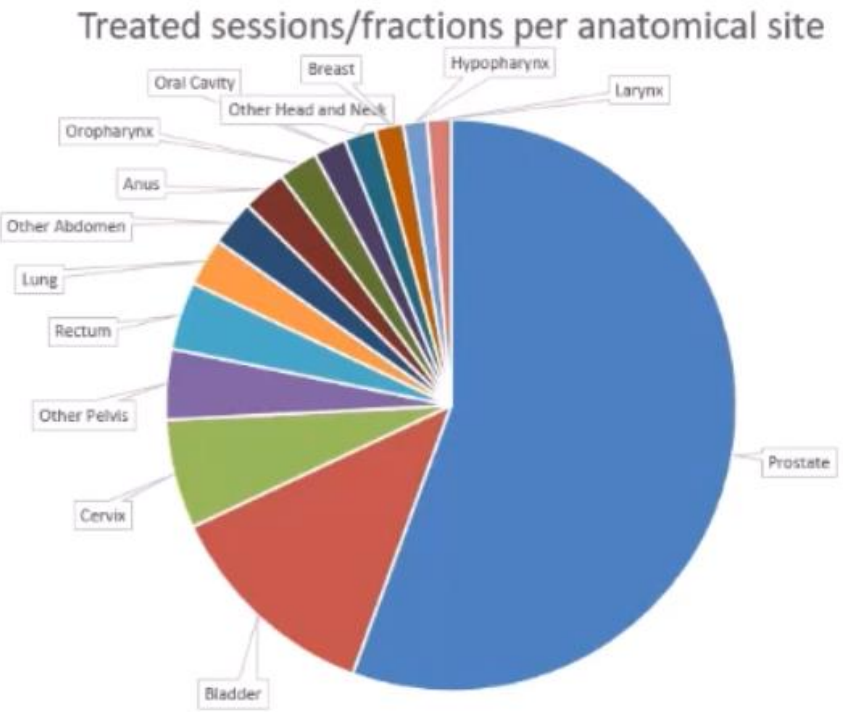
Adaptive Radiotherapy

87 %

of the time, the adaptive plan is selected

Adaptive Sessions

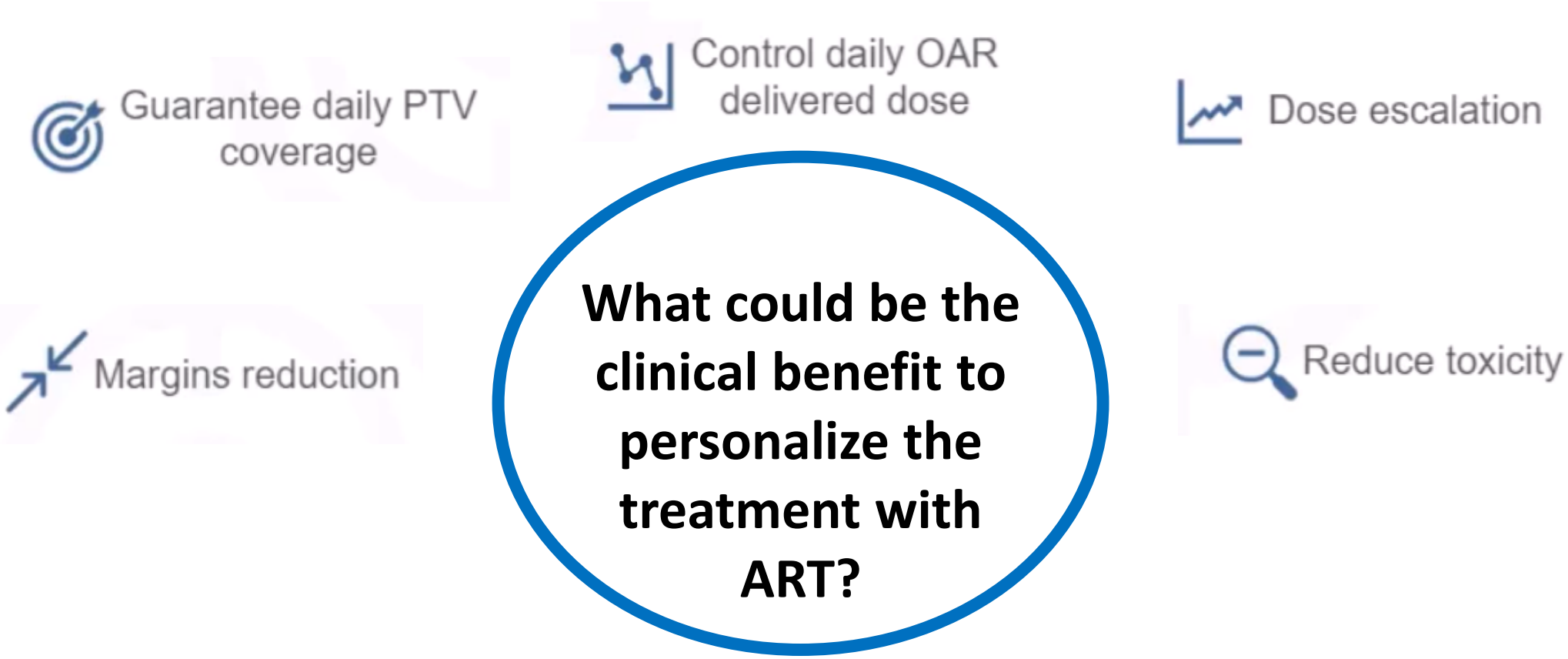
System use per anatomical site



Analysis based on 89 institutions in EMEA, APJI, and Americas from September 2019 through July 31, 2023
*August 2020 data are incomplete

varian
A Siemens Healthineers Company

Adaptive Radiotherapy



Hypothesis: Potential Benefits

Experiences at Inselspital: Esophageal Cancer

Esophageal cancer: Large volumes

Expert Consensus Contouring Guidelines for Intensity Modulated Radiation Therapy in Esophageal and Gastroesophageal Junction Cancer

Abraham J. Wu, MD,* Walter R. Bosch, DSc,† Daniel T

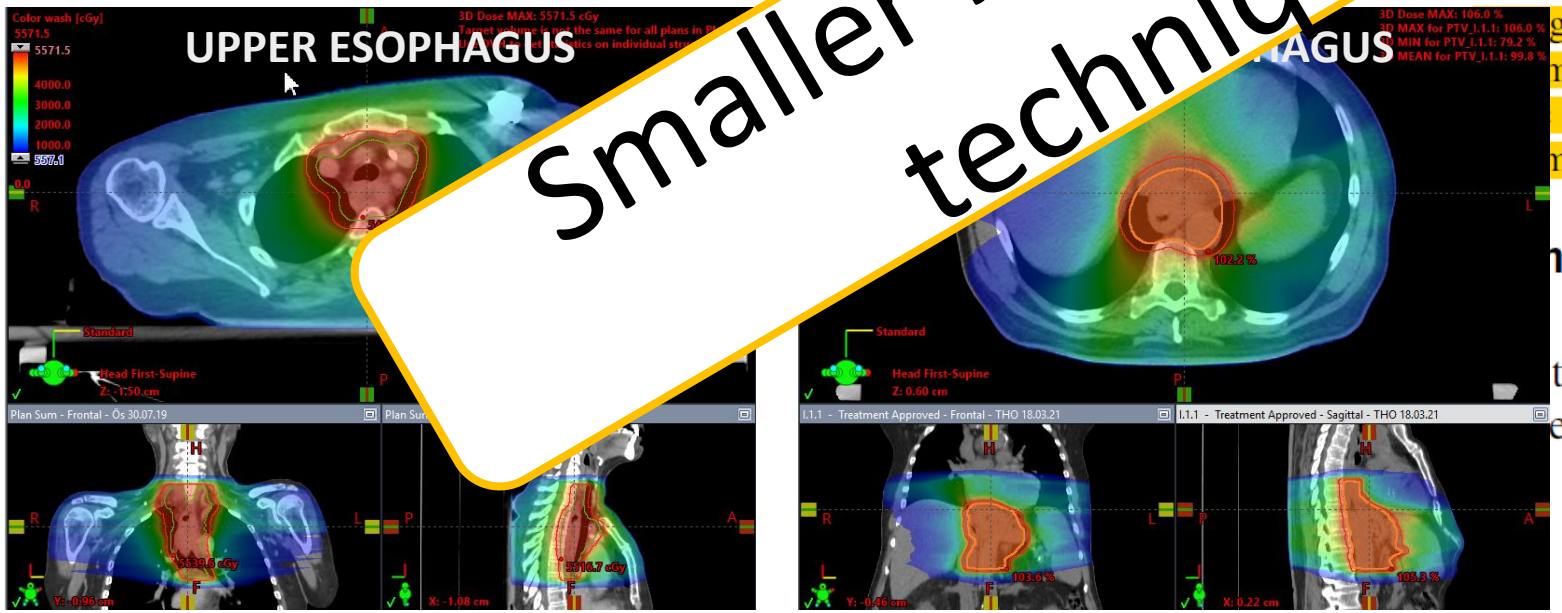
Radial bor
In ge (including any
1-cm margin in all
rom the outer esophageal

be limited to 0.5 cm into uninvolved liver. Excluding the liver and heart from the CTV entirely is reasonable if robust motion management techniques, such as respiratory g or an internal target volume approach, are used to mize the possibility that a CTV border based on a simulation scan is transgressed during radiation ment as a result of tumor or organ motion. It was also

nes

to PTV delineation, the panel recommended e CTV by 0.5 to 1 cm in all directions,

Smaller margins / other techniques?



Esophageal cancer: OARs

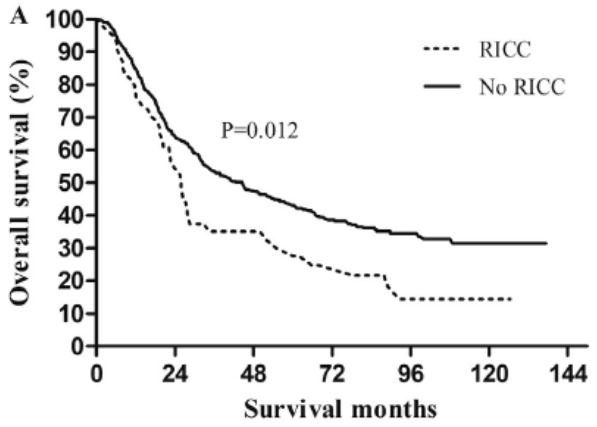
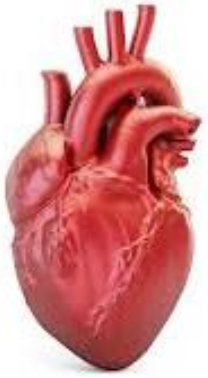


Fig. 2. Overall survival according to (A) radiation-induced cardiac complications (RICC), and (B) radiation-induced pulmonary complications (RIPC).



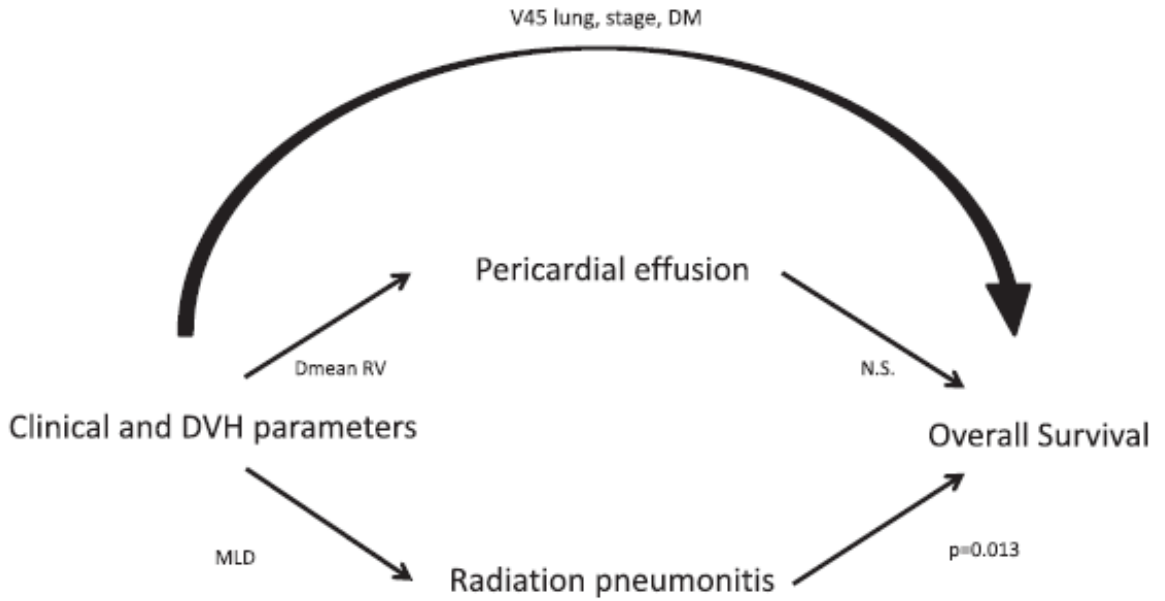
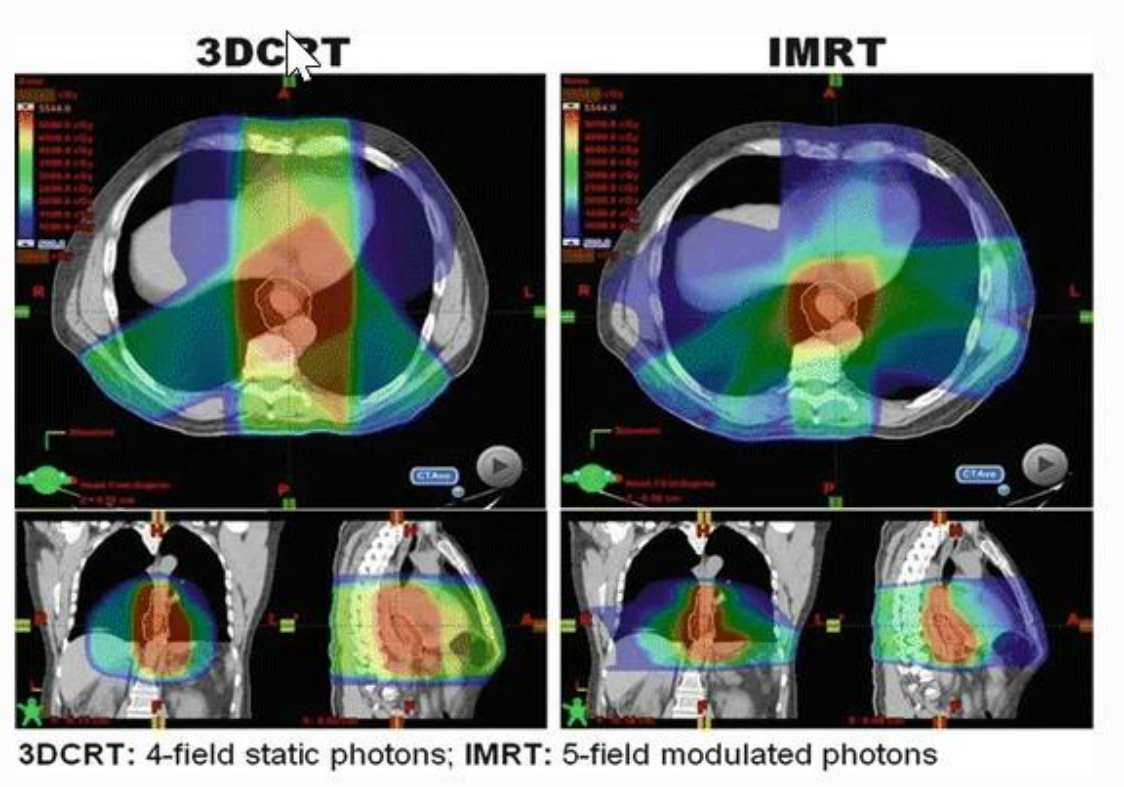


Fig. 2. Overview of the performed analyses and its relationships and predictive factors (Vmean RV = mean dose on the right ventricle, MLD = mean lung dose, DM = diabetes Mellitus).

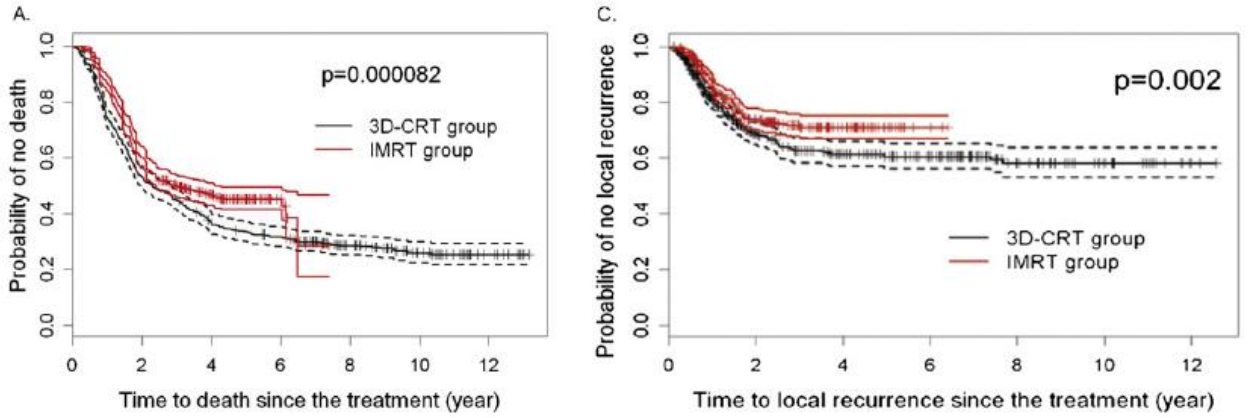
J.C. Beukema et al. / Radiotherapy and Oncology 149 (2020) 222–227

Could we improve something as radiation oncologists?

Esophageal cancer: RT techniques



3DCRT: 4-field static photons; **IMRT:** 5-field modulated photons



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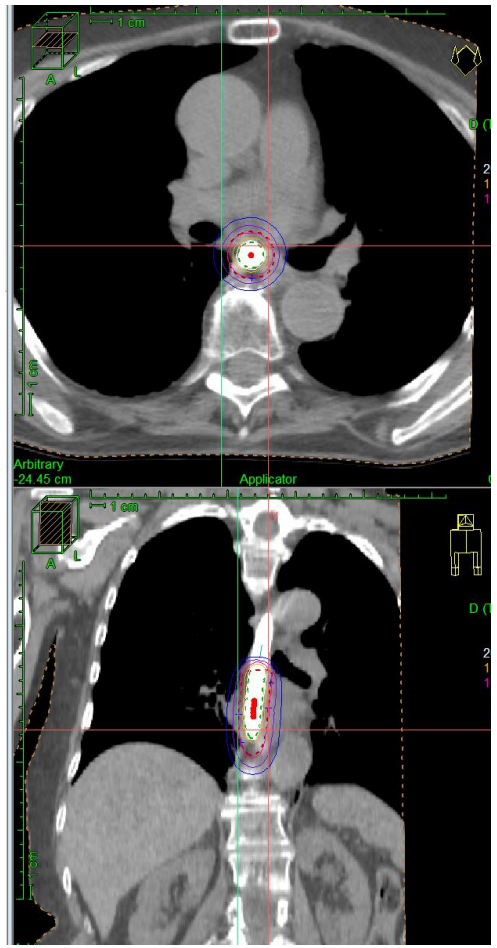
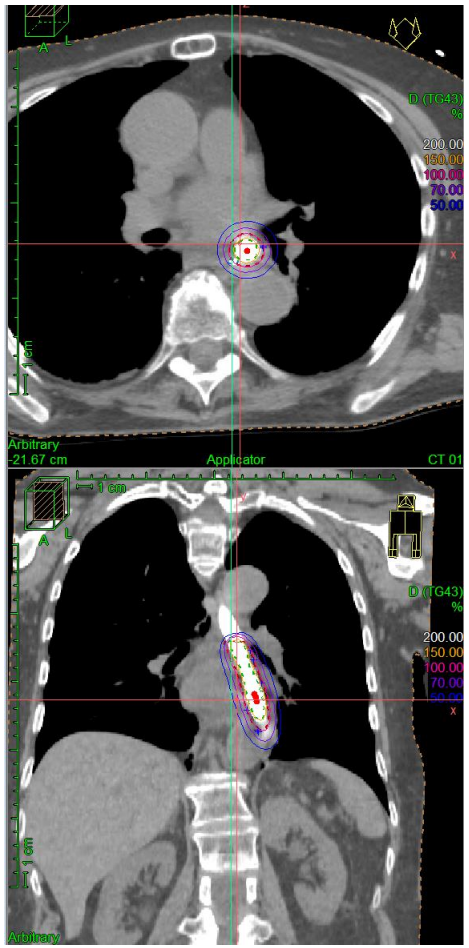
Radiotherapy technique matters!

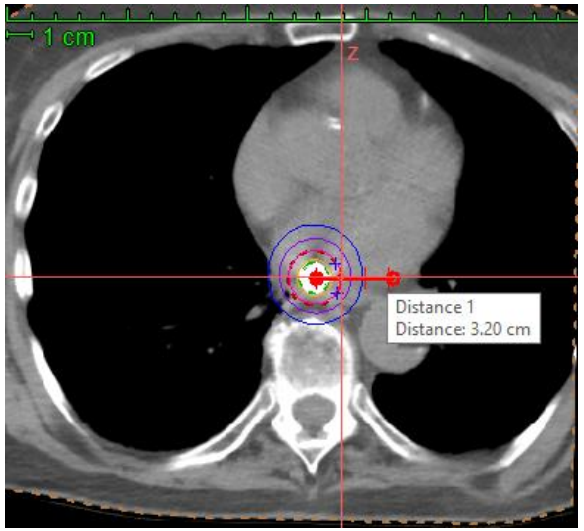
Esophageal cancer: Motion management

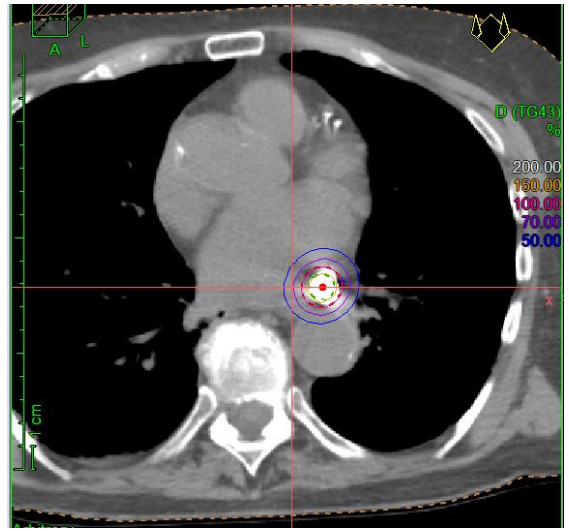
1/3 Brachytherapy



3/3 Brachytherapy







The motion could not be corrected in IGRT mode!

Esophageal cancer: Adaptive RT

An in-silico assessment of the dosimetric benefits of MR-guided radiotherapy for esophageal cancer patients

Mick Boekhoff [a,*,2], Ingmar Defize [a,b], Alicia Borggreve [a,b], Richard van Hillegersberg [b], Alexis Kotte [a], Jan Lagendijk [a], Astrid van Lier [a], Jelle Ruurda [b], Noriyoshi Takahashi [a,c], Gert Meijer [a,*,1,3]

[a] Department of Radiation Oncology; [b] Department of Surgery; and [c] Department of Radiation Oncology, Tohoku University

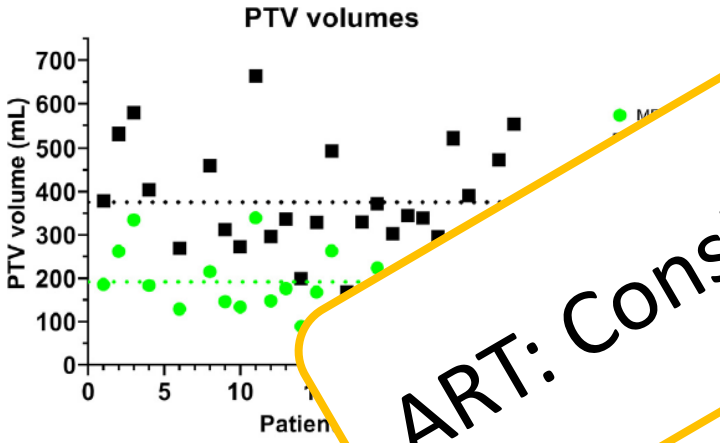
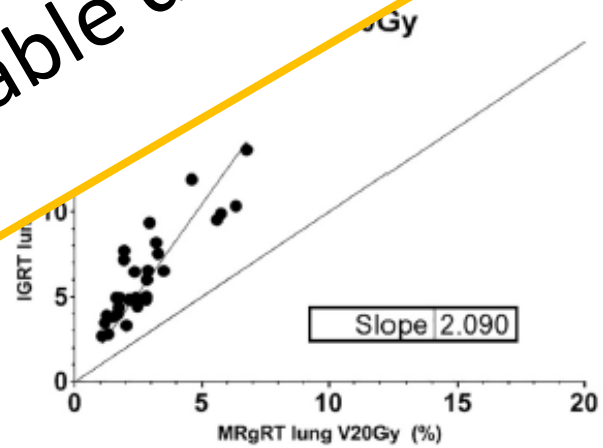
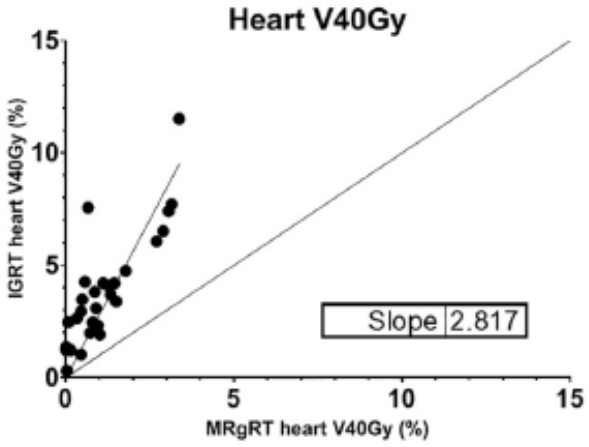


Fig. 2. PTV volumes of IGRT plans (black … …en circles). Average PTV volume for IGRT plans with CT … … and 12 mm in AP, LR and CC direction, respectively, was 3… …ashed line) and for MRgRT plans with 2 mm axial and 5 mm CC C… …margins the average PTV volume was 194 cm^3 (green dashed line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

ART: Considerable dose reduction to OARs!





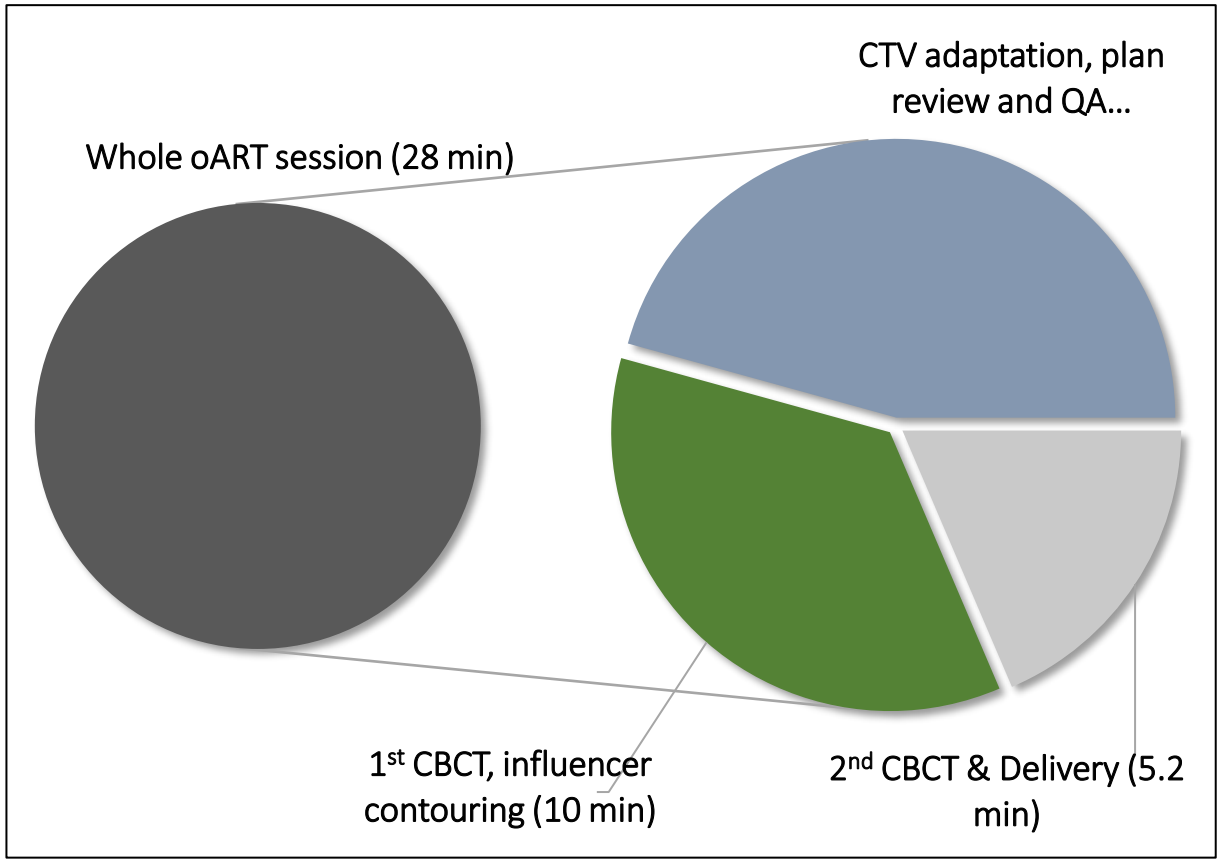
Esophageal cancer (Inselspital)

- **First 10 patients** receiving oART
- Prescription dose 50.4 Gy in 28 fractions
- Same margin concept as in non-adaptive situation
- **280 fractions**
- **560 manual plan reviews (adaptive vs. scheduled)**
  - mean heart dose, lung $V20_{Gy}$, minimal (=D99%) and coverage (=D95%) CTV & PTV dose
  - Duration time of each oART workflow step

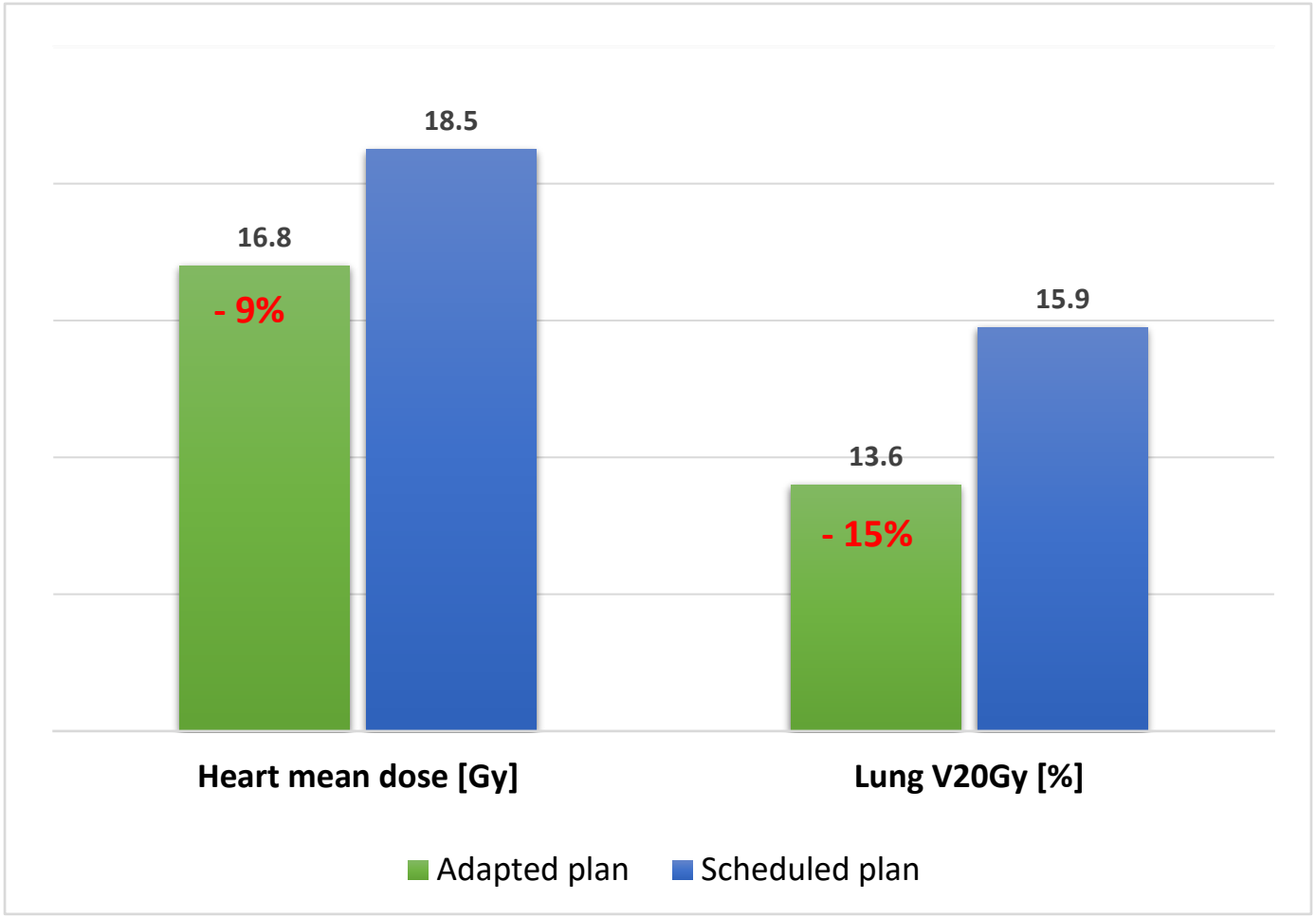
Characteristics	Patients (n=10)
Age [years]	72 (35 – 85)
Sex	
Female	3 (30)
Male	7 (70)
Histology	
Adeno-Ca.	8 (80)
SCC	2 (20)
Tumor localization	
Middle esophagus	2 (20)
Lower esophagus	8 (80)
T-Stage	
T2	2 (20)
T3	8 (80)
N-Stage	
N0	3 (30)
N1-2	7 (70)
Treatment concept	
Definitive RCHT	3 (30)
Neoadjuv. RCHT	7 (70)

Esophageal cancer: Adaptive RT (Inselspital)

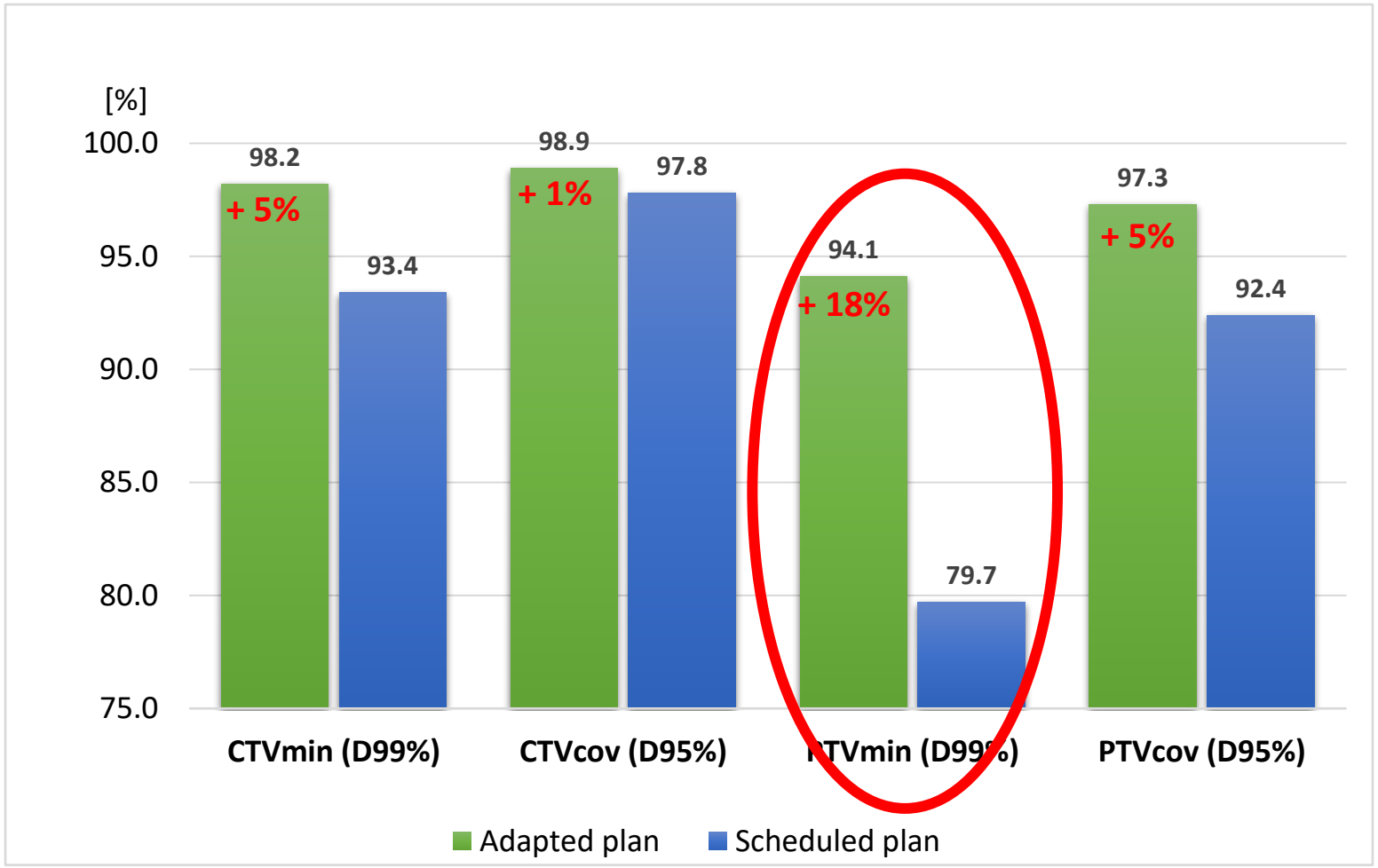
- **28 min** = median time for whole session (range 14.8 – 43.3min)
- **59%** CTV adaptation by MD necessary after automatic propagation
- **99%** adapted treatment plan selected



Esophageal cancer: Adaptive RT (Inselspital)



Esophageal cancer: Adaptive RT (Inselspital)



Esophageal cancer: Adaptive RT (Inselspital)

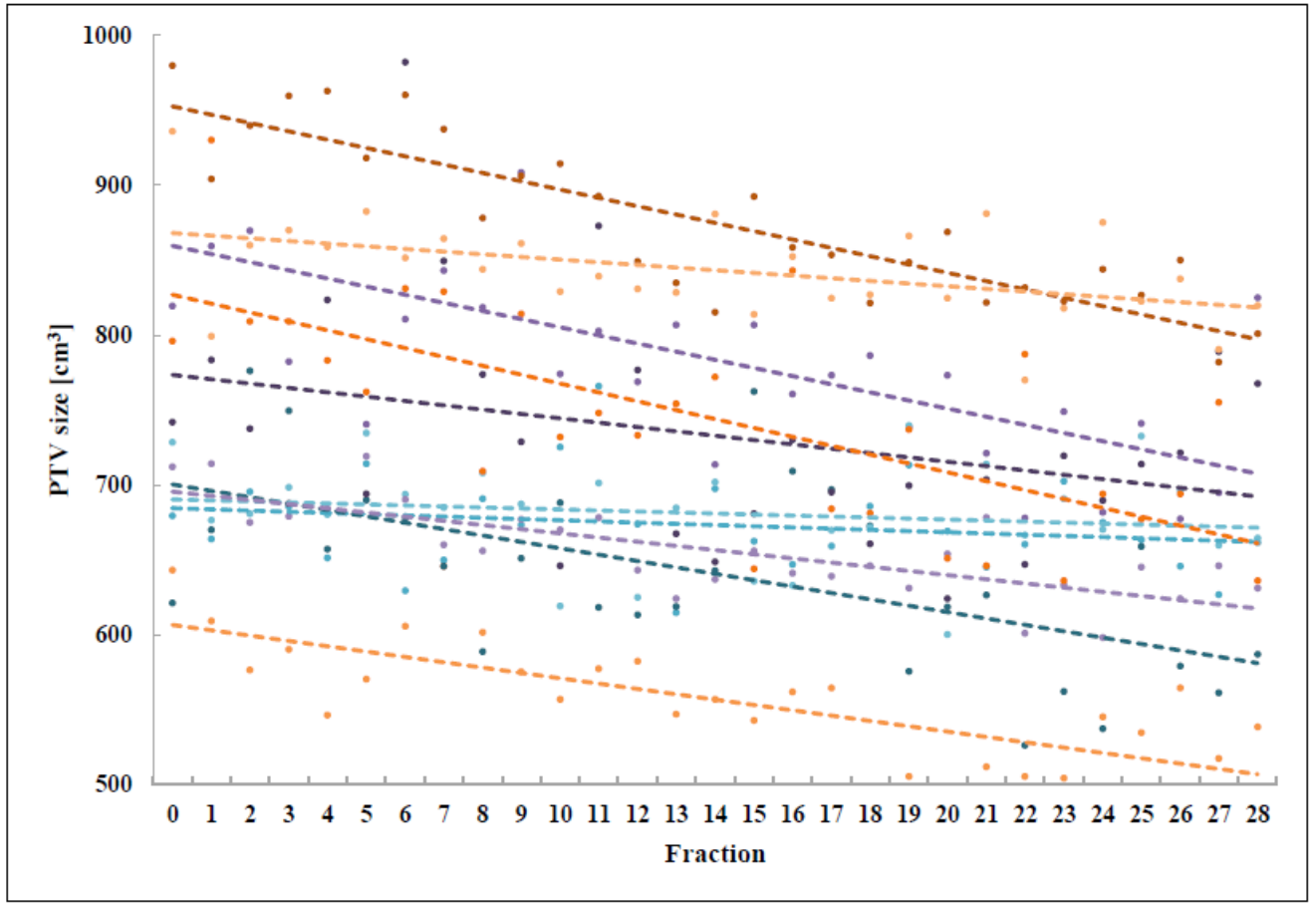
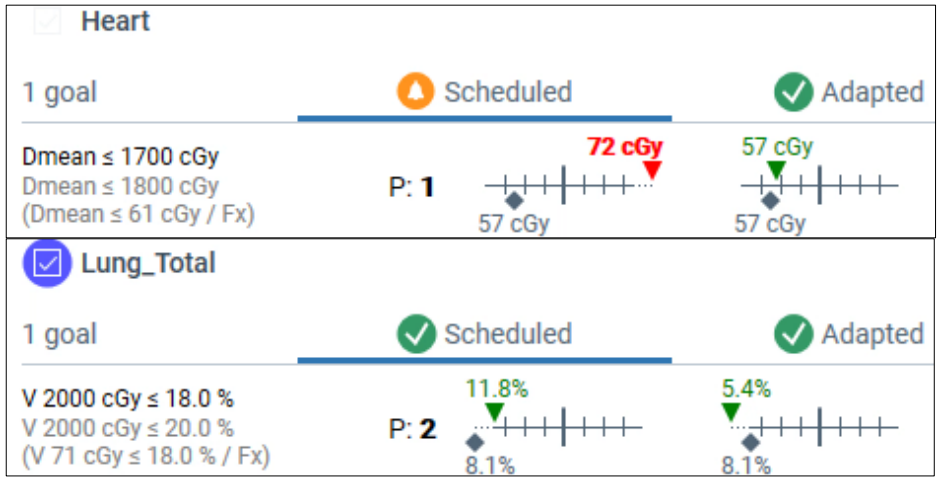


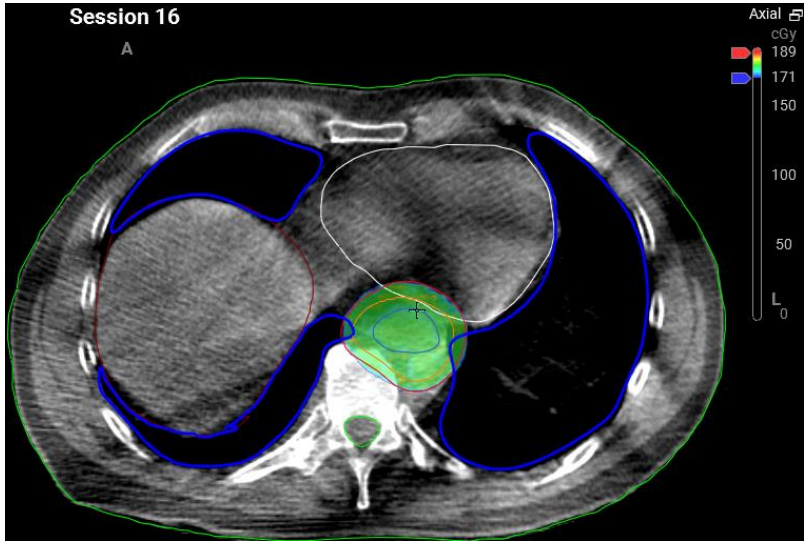
Fig. 3: Development of the planning target volume (PTV) size over the period of all 28 oART sessions. Every color represents a patient and the dashed lines represent linear regressions of the corresponding dots. Fraction 0 describes the PTV size before the start of oART, i.e. on the planning

Esophageal cancer (Adaptive RT)

Scheduled plan

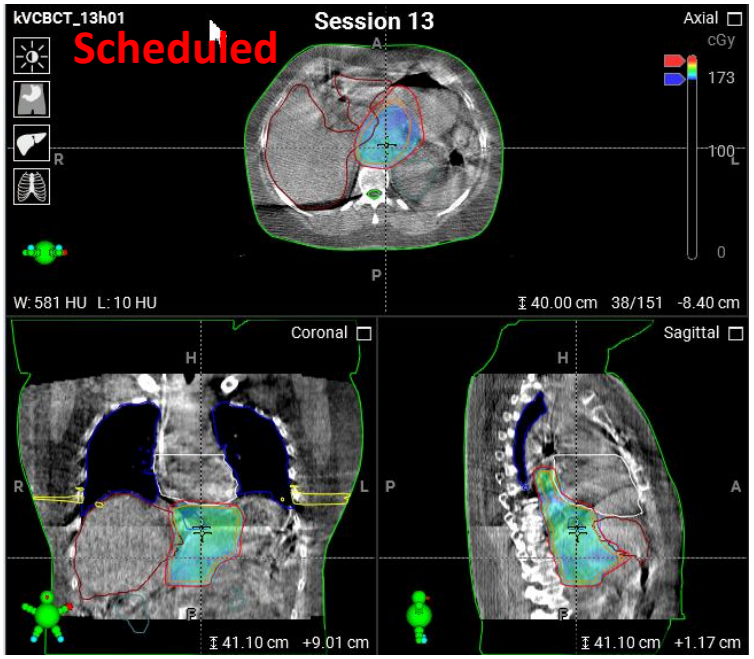


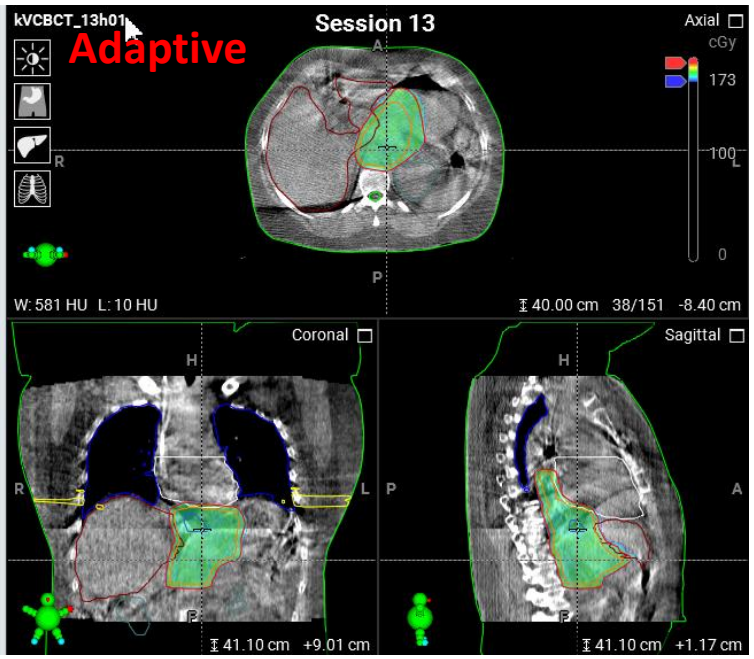
Adapted plan

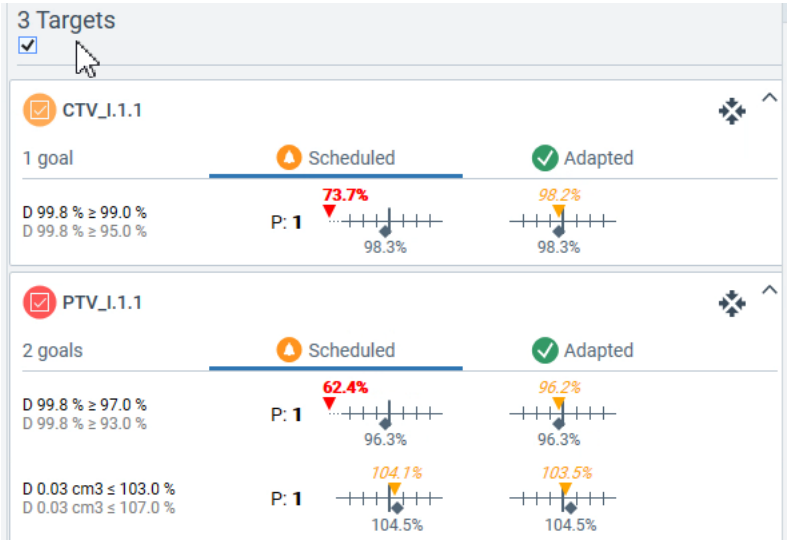


Esophageal cancer (Adaptive RT)

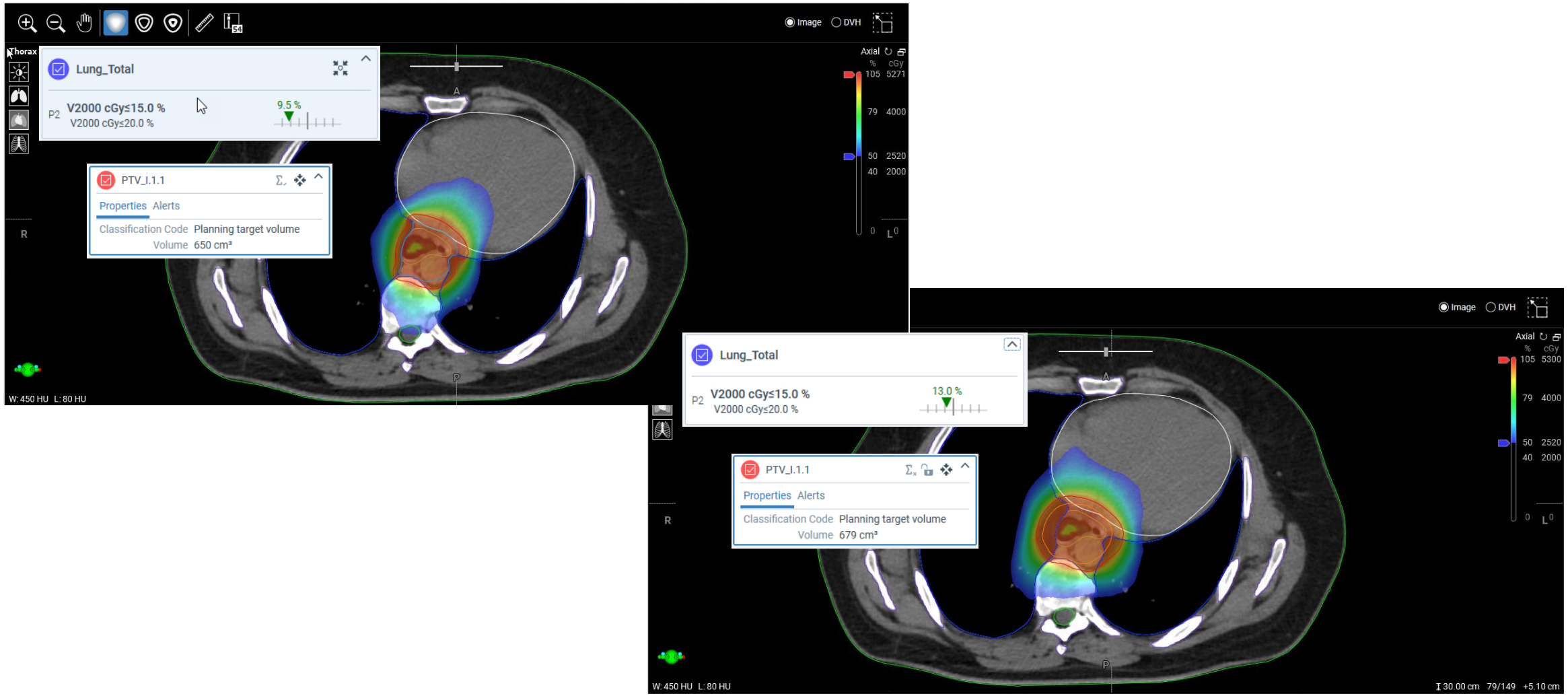
- 47yr old female patient with GEJ-cancer (T3, N0)







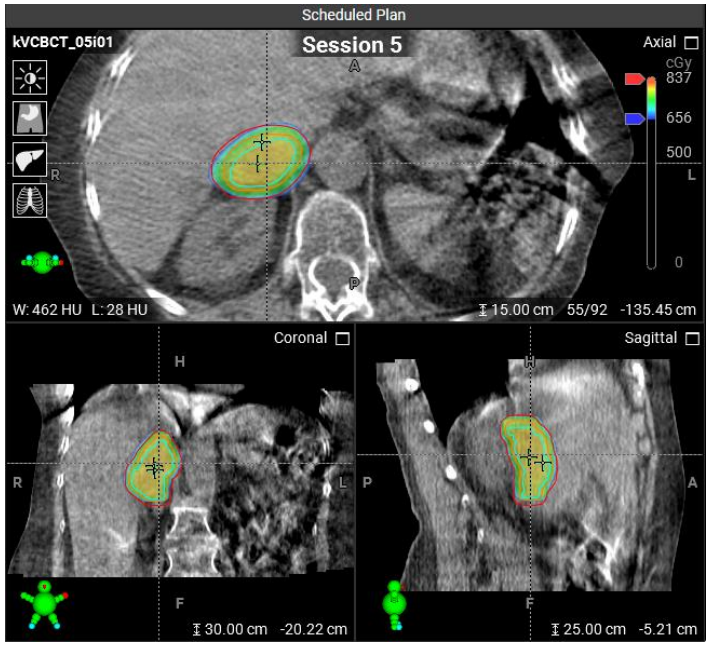
Esophageal cancer: Margin reduction

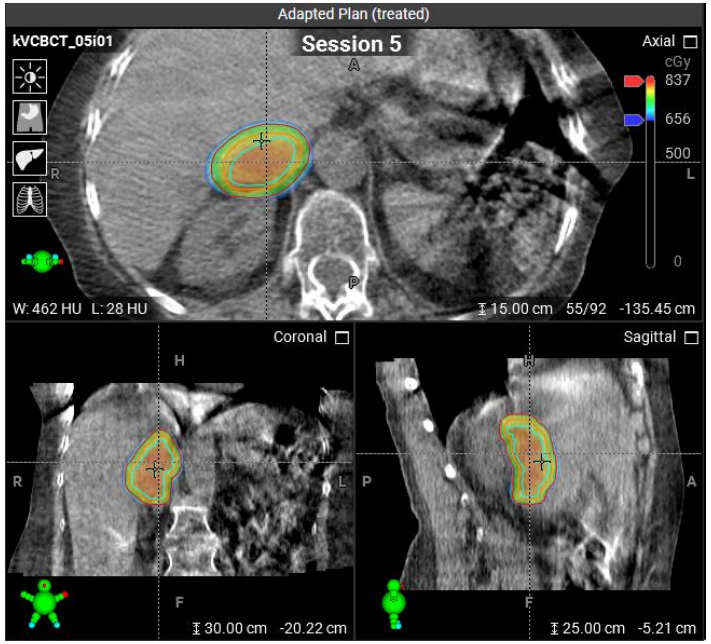


Experiences at Inselspital: SBRT for adrenal metastases

SBRT/ART for adrenal metastasis

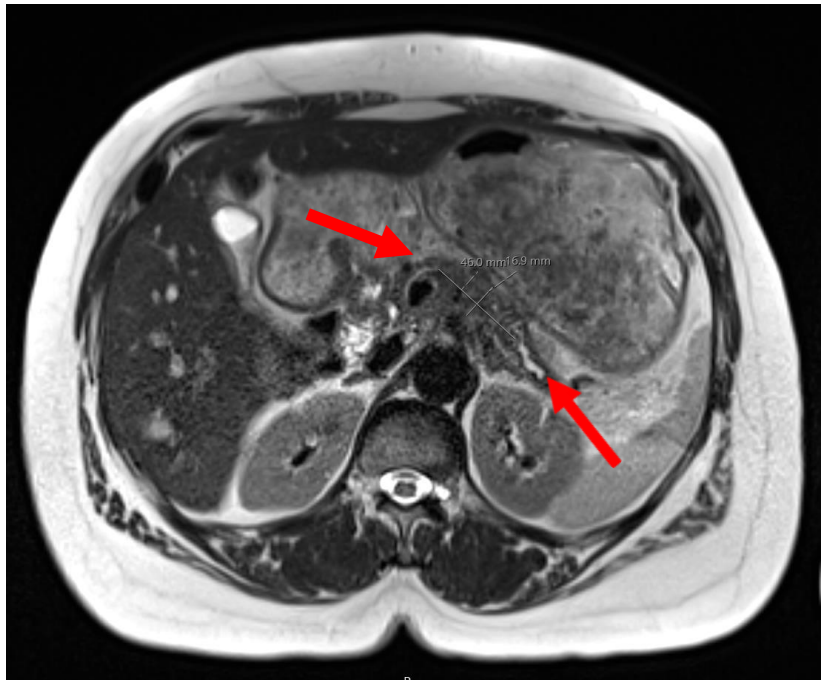
- PTV size > 3cm
- 4D PL-CT
- ITV
- 5-7 fractions
- >10 patients

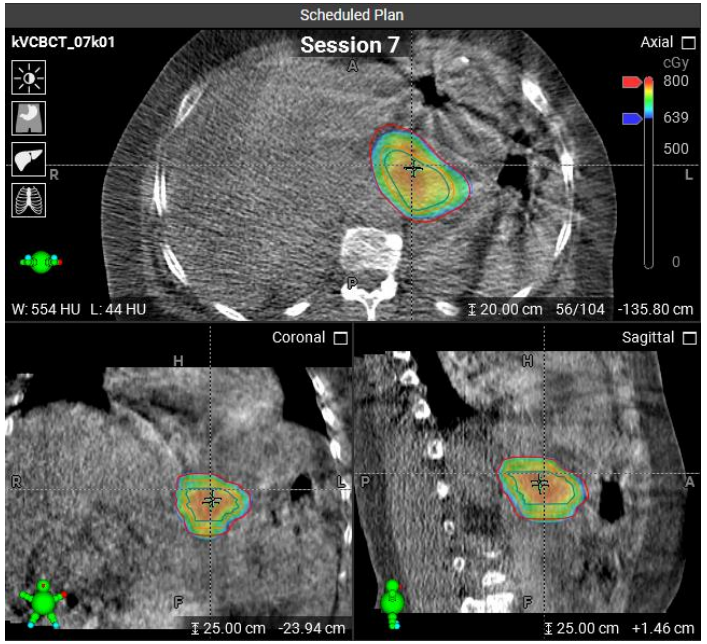


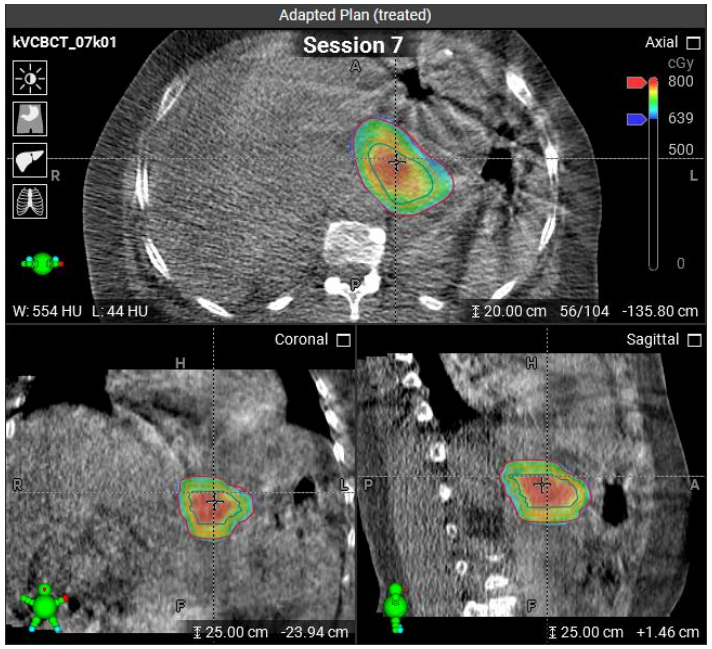


SBRT/ART for pancreatic cancer

- PTV size > 3cm
- 4D PL-CT
- ITV
- 5-7 fractions
- 2 patients







ART: Challenges and future perspective

- Time, resources and expertise
- CBCT quality
- Organ motion management (DIBH, identifier?)
- Data mining from Ethos

- ART for all tumor sites?
- Oncological outcomes?

Thank you for your attention!