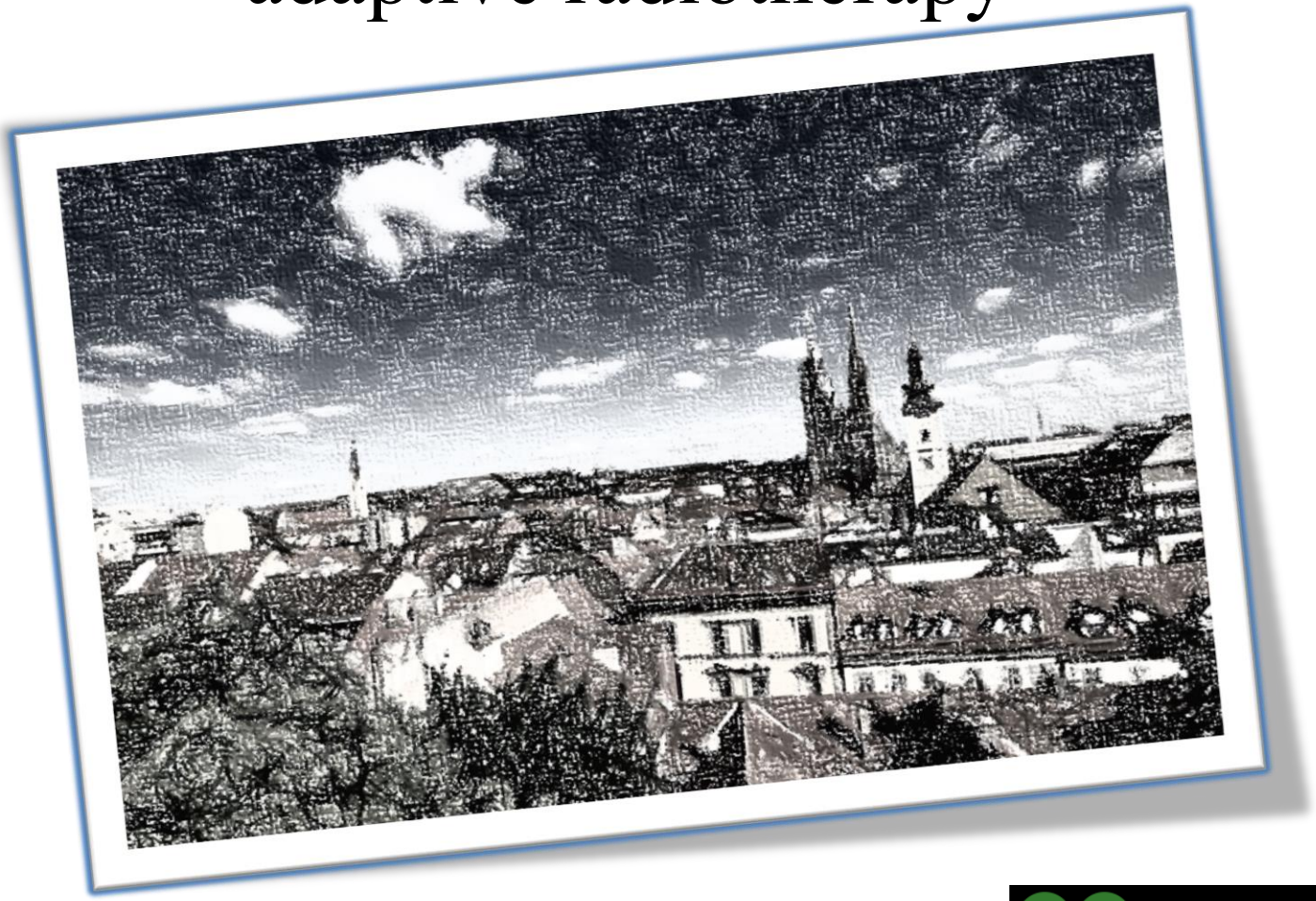
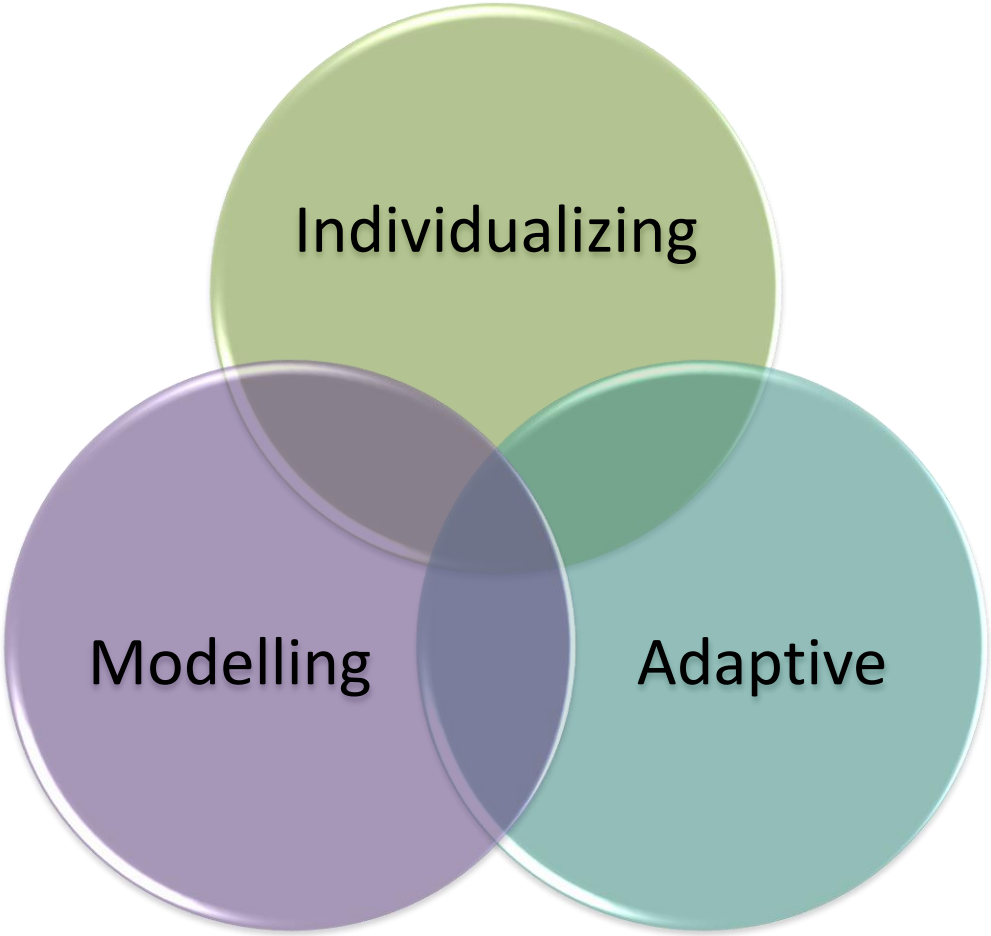
Adaptive planning in the context of adaptive radiotherapy



Danilo Pasini
Radiotherapy Department
Università Cattolica del Sacro Cuore - Rome

Zagreb 6/8 November

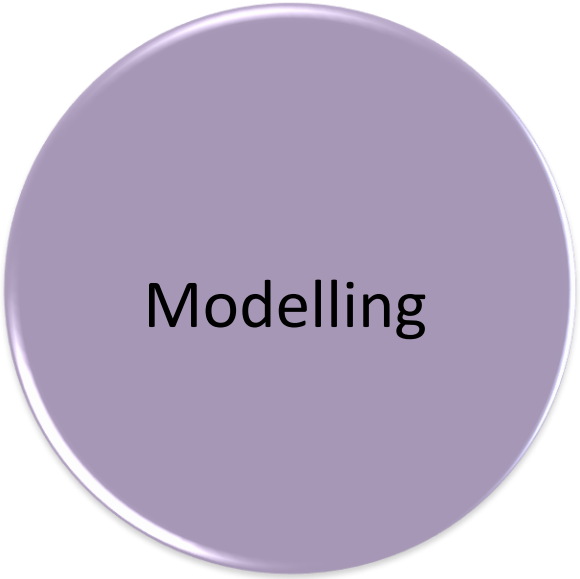
Knowledge Based Oncology



Knowledge Based Oncology

Tailoring a RT treatment on each patient based on **prognostic/predictive** features

Knowledge Based Oncology



to develop **multimodality predictive factors** in order to define, “in antis”, the **disease progress and the following modality of treatment**

Knowledge Based Oncology

to adapt the treatment **during the treatment itself** modifying the treatment based on the **actual accumulated dose** and on the **tumor response** and OaR modifications.

ADAPTIVE PLANNING

- Replanning procedures
  - Plan library procedures
    - Dose Painting procedures

Adaptive planning

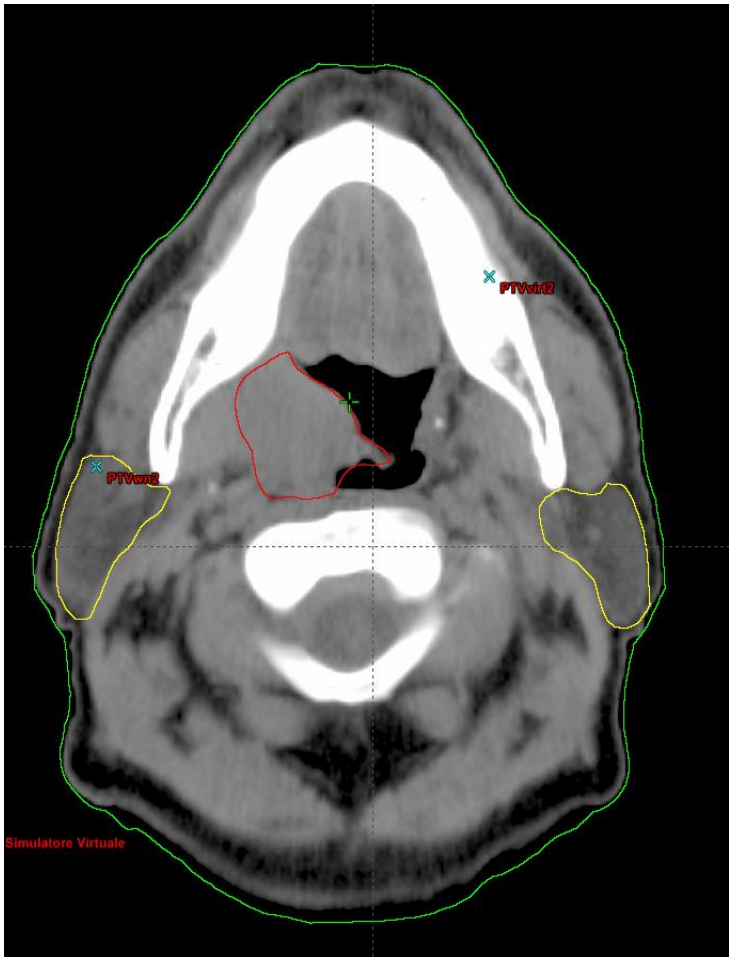
REPLANNING

Replanning procedures based on the systematic correction of the dose distribution following the patient shrinkage and the target and OaR volume variations.

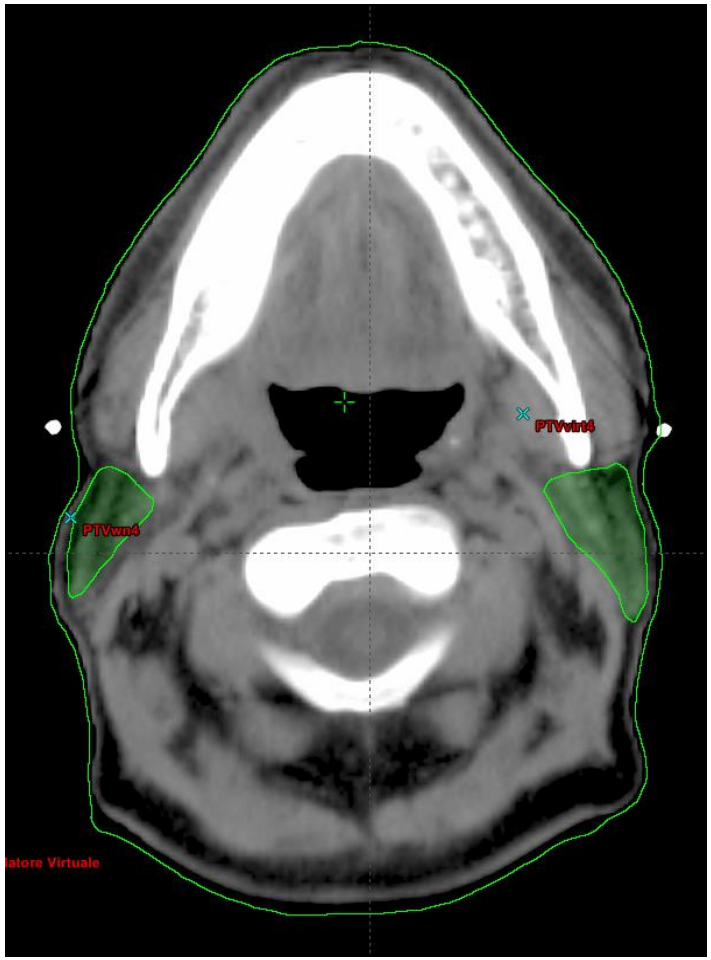
- Replanning based on a new CT
- Replanning based on CBCT
- Replanning based on *in-vivo* dosimetry

Adaptive planning

REPLANNING ON A NEW CT



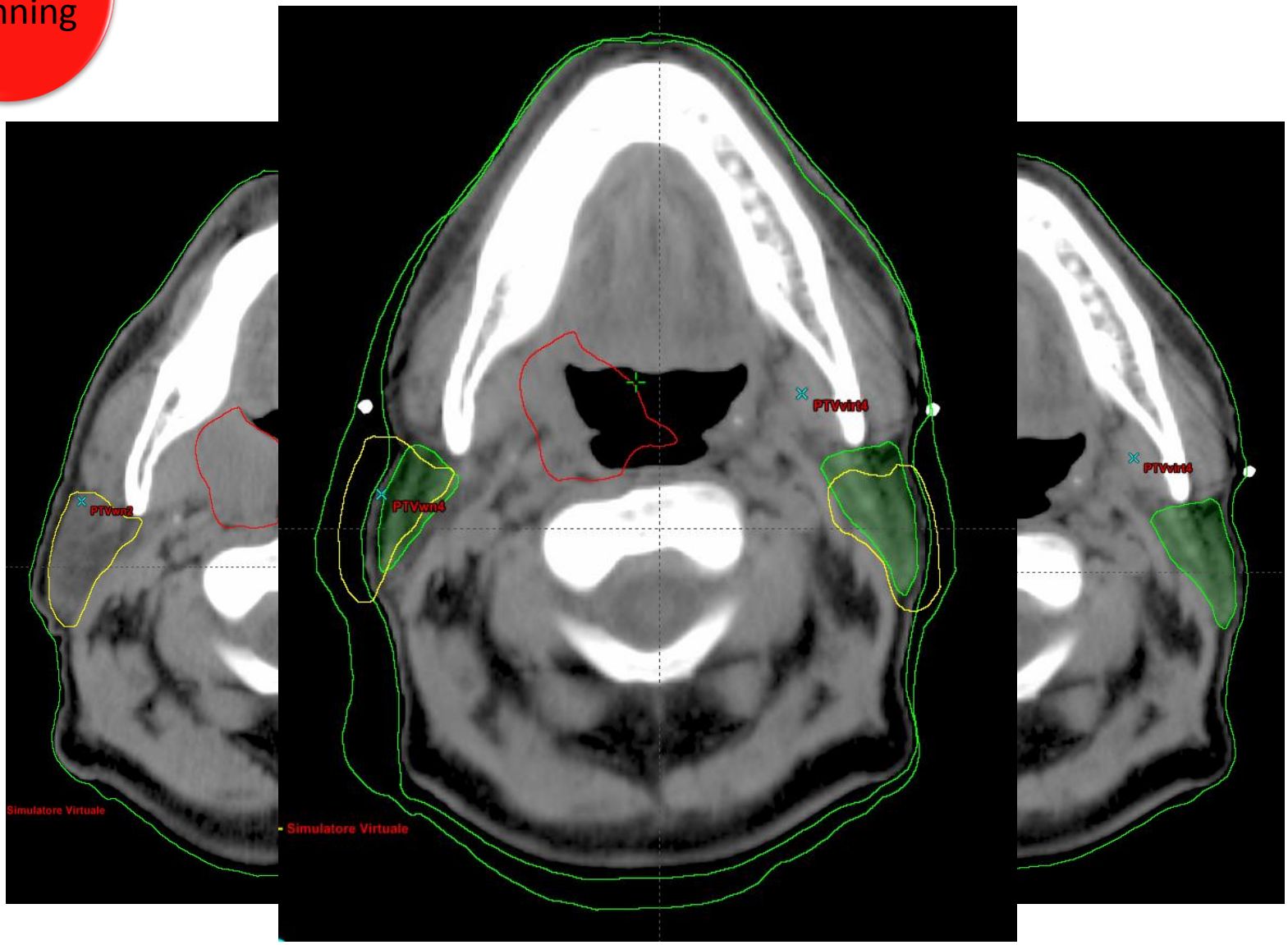
Planning CT



New CT

Adaptive planning

REPLANNING ON A NEW CT



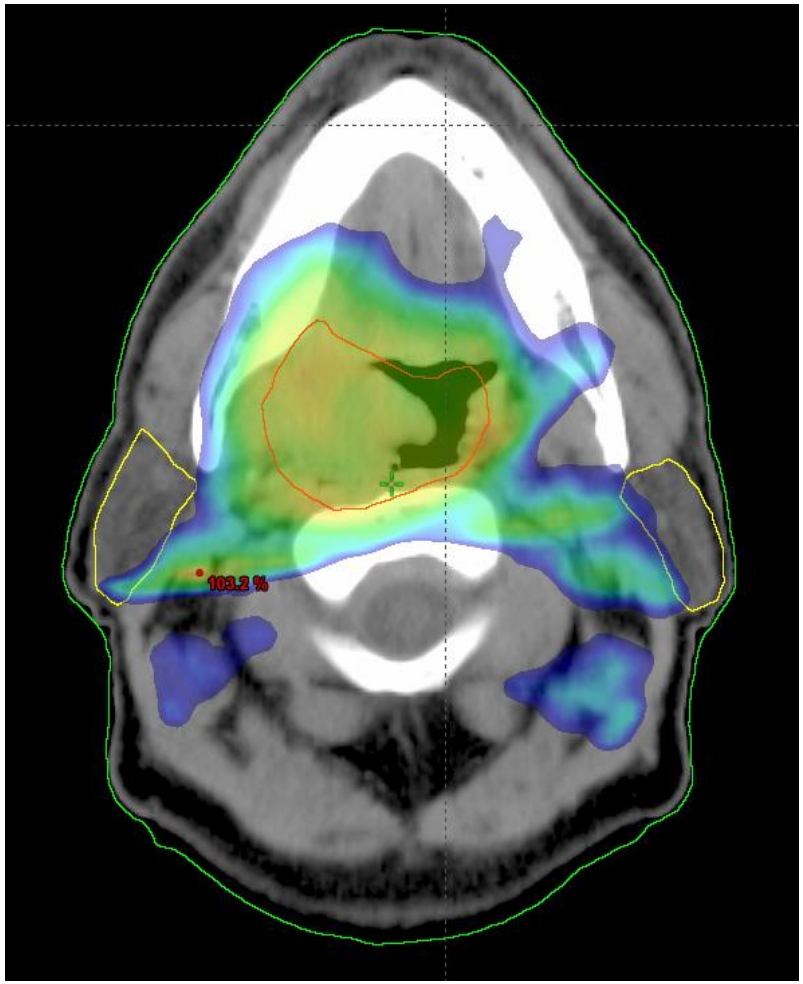
Planning CT

New CT

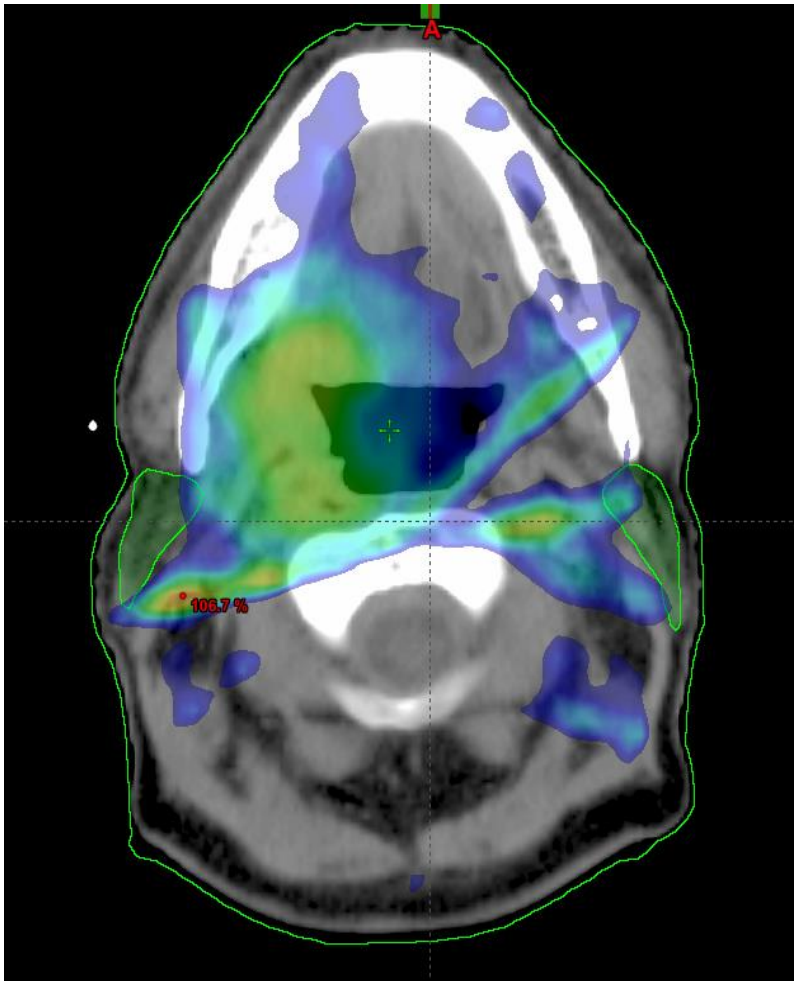
Adaptive planning

REPLANNING ON A NEW CT

Replanning after a determinate dose (30/35Gy)



Dose distribution on planning TC



Dose distribution on new TC

Adaptive planning

REPLANNING ON A NEW CT

Relanning on H&N: when??

82 pts assessed by 4 CT:
1°before
2°at 15th fraction (30Gy)
3°at the end
4° after 2 months

These gland volume reductions correlated significantly with the mean dose to the irradiated glands; the spared glands showed few changes……**Volume loss at higher doses (>30 Gy)**
to the glands was significantly larger than at low doses (<30 Gy; P < .001).

Radiation-induced volume changes in parotid and submandibular glands in patients with head and neck cancer receiving postoperative radiotherapy: a longitudinal study
Wang ZN, Yang C, Zhang ZY, et al
Laryngoscope 2009

Adaptive planning

REPLANNING ON A NEW CT

Relanning on H&N: when??

174 pts assessed by MVCT and KVCT

IPV – Age clinical predictors

***Dmean* – V40** dosimetric predictors

Δv (cc) = -2.44+0.076 *Dmean* + 0.279 IVP (cc)

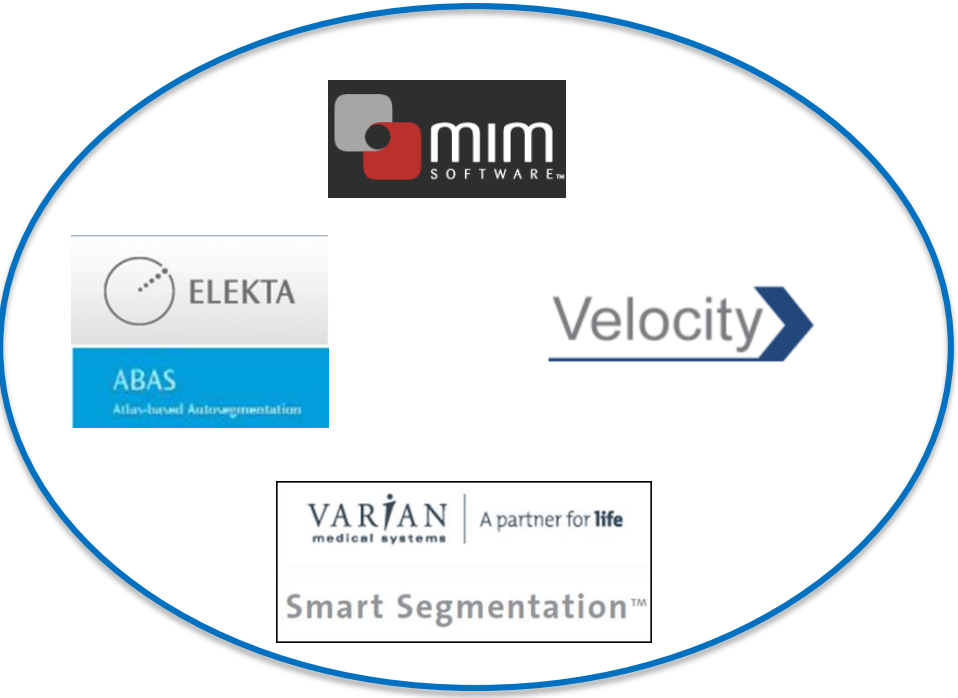
Δv (%) = 34.24+0.192 V40(%)-0.2203 age (year)

A two-variable linear model of parotid shrinkage during IMRT for head and neck cancer.
Broggi S, Fiorino C, Dell'Oca I, Dinapoli N, et al.
Radiotherapy and Oncology; 2010

Adaptive planning

REPLANNING ON A NEW CT

The role of the AUTOCONTOURING systems

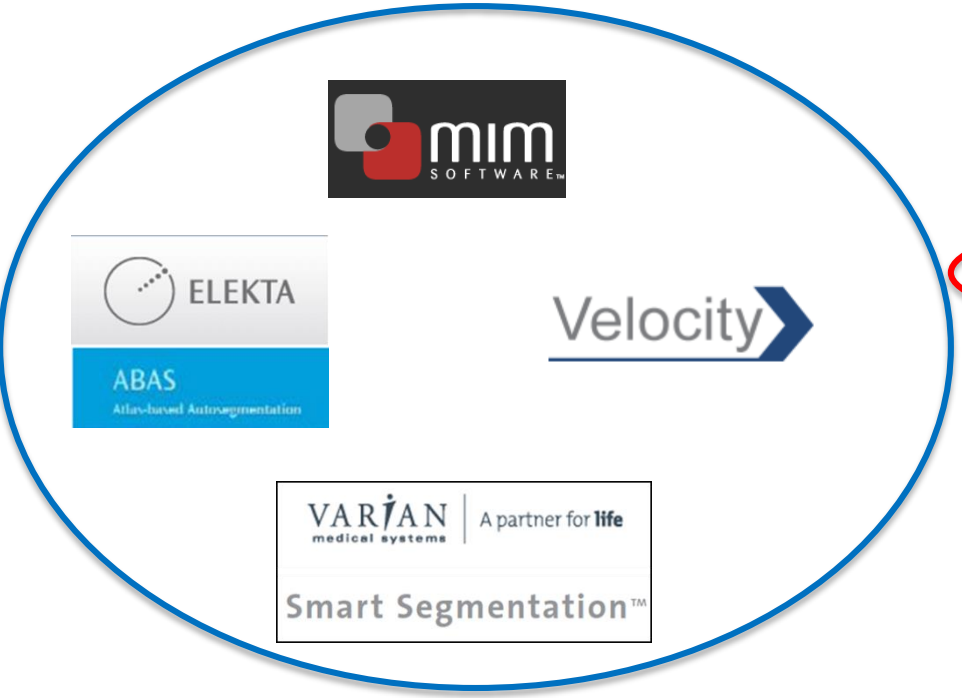


- **MODEL BASED APPROACH**
- **ATLAS BASED APPROACH**
- **HYBRID APPROACH**

Adaptive planning

REPLANNING ON A NEW CT

The role of the AUTOCONTOURING systems

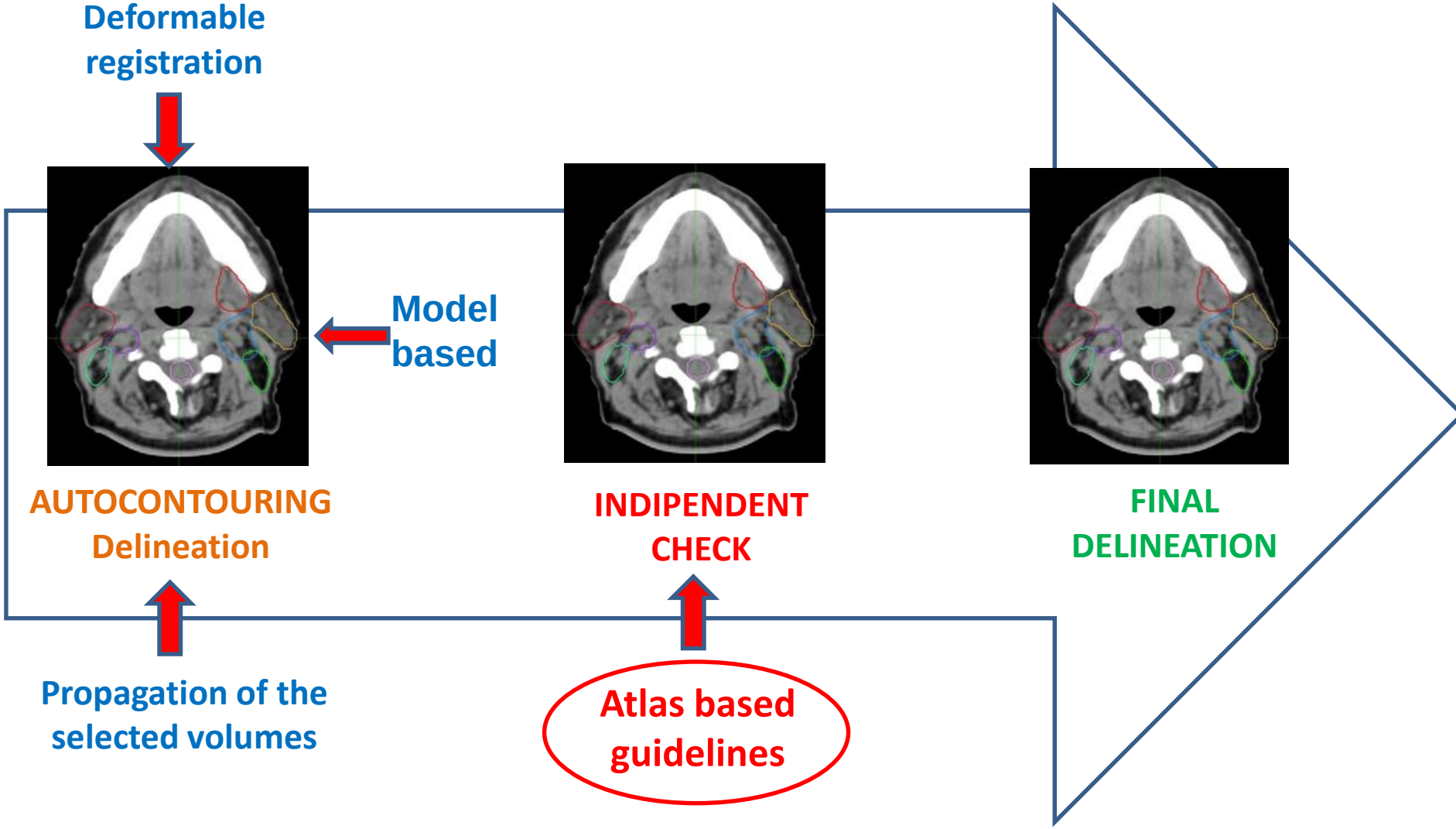


- **MODEL BASED APPROACH**
- **ATLAS BASED APPROACH**
- **HYBRID APPROACH**

Adaptive planning

REPLANNING ON A NEW CT

AUTOCONTOURING WORKFLOW



Adaptive planning

Workflow efficiency: TIME FACTOR

Manual delineation VS Autocontouring

Head & Neck

Clinical validation of atlas-based auto-segmentation of multiple target volumes and normal tissue (swallowing/mastication) structures in the head and neck.

Teguh DN, Levendaq PC, Voet PW, et al.

Int J Radiation Oncol Biol Phys. 2011

"……Although editing of the autocontours is inevitable, a substantial time reduction was achived using editing, instead of manual contouring ***180 vs 66 min"***

ELEKTA

ABAS

Atlas-based Autosegmentation

Automatic delineation for replanning in nasopharynx radiotherapy: What is the agreement among experts to be considered as benchmark?

Mattiucci GC, Boldrini L, Pasini D, et al.

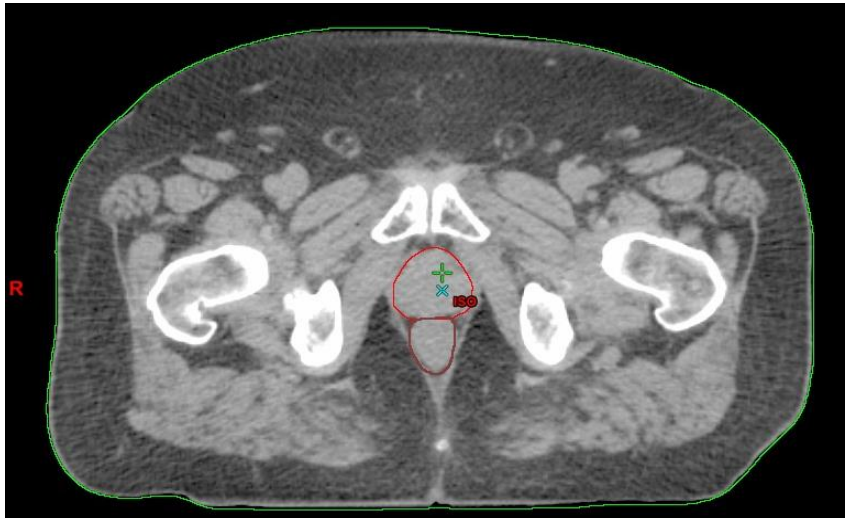
Acta Oncologica, 2013; 52: 1417–1422

"…..mean saved time in Structure Set B of ***35 min"***

Velocity

Adaptive planning

REPLANNING ON CBCT



Use the modern potentiality offered by the IGRT technology

Adaptive planning

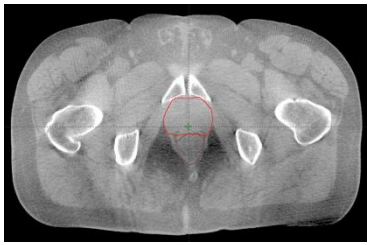
REPLANNING ON CBCT

1°day

2°day

3°day

4°day

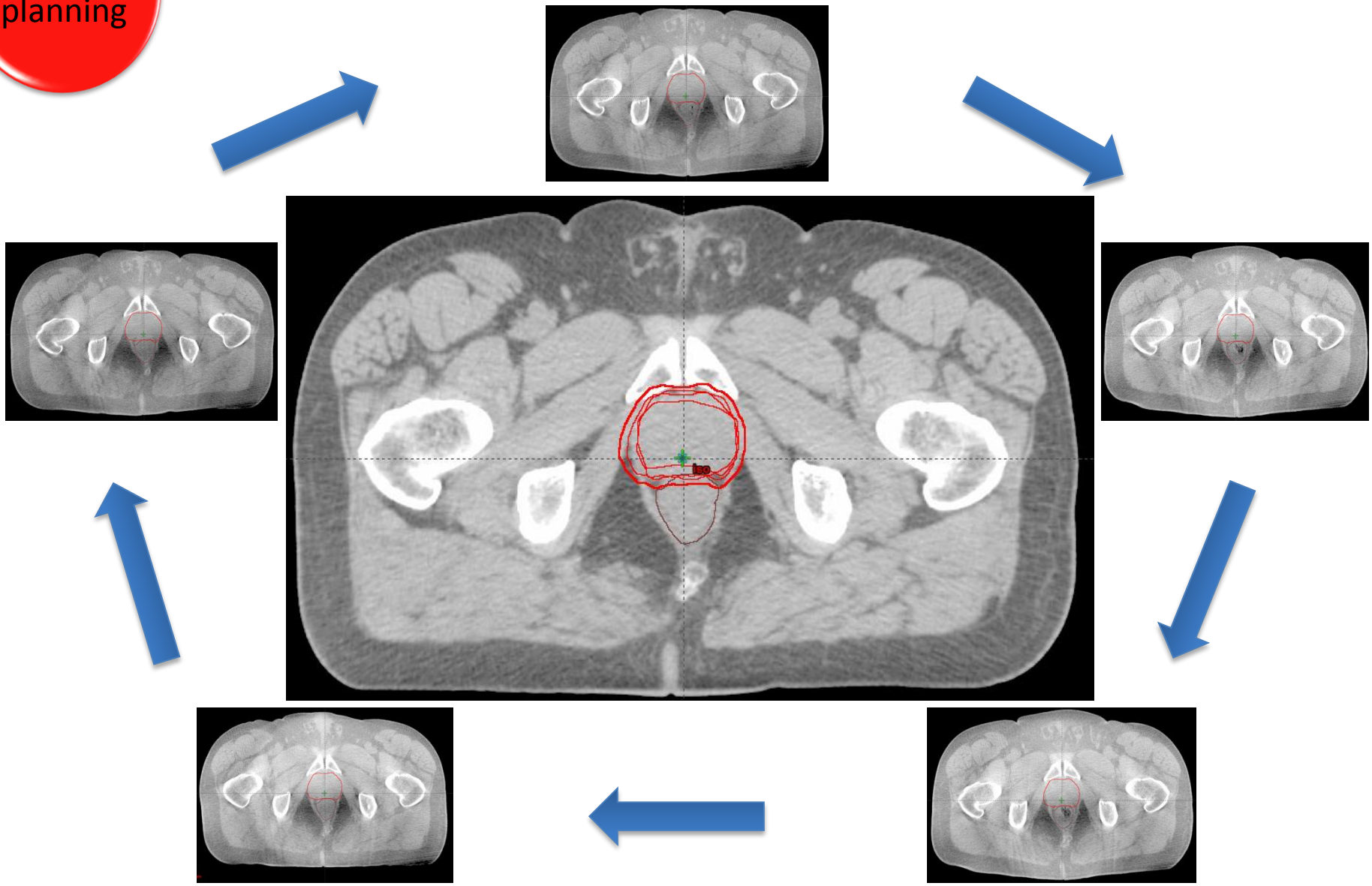


5°day

Our experience

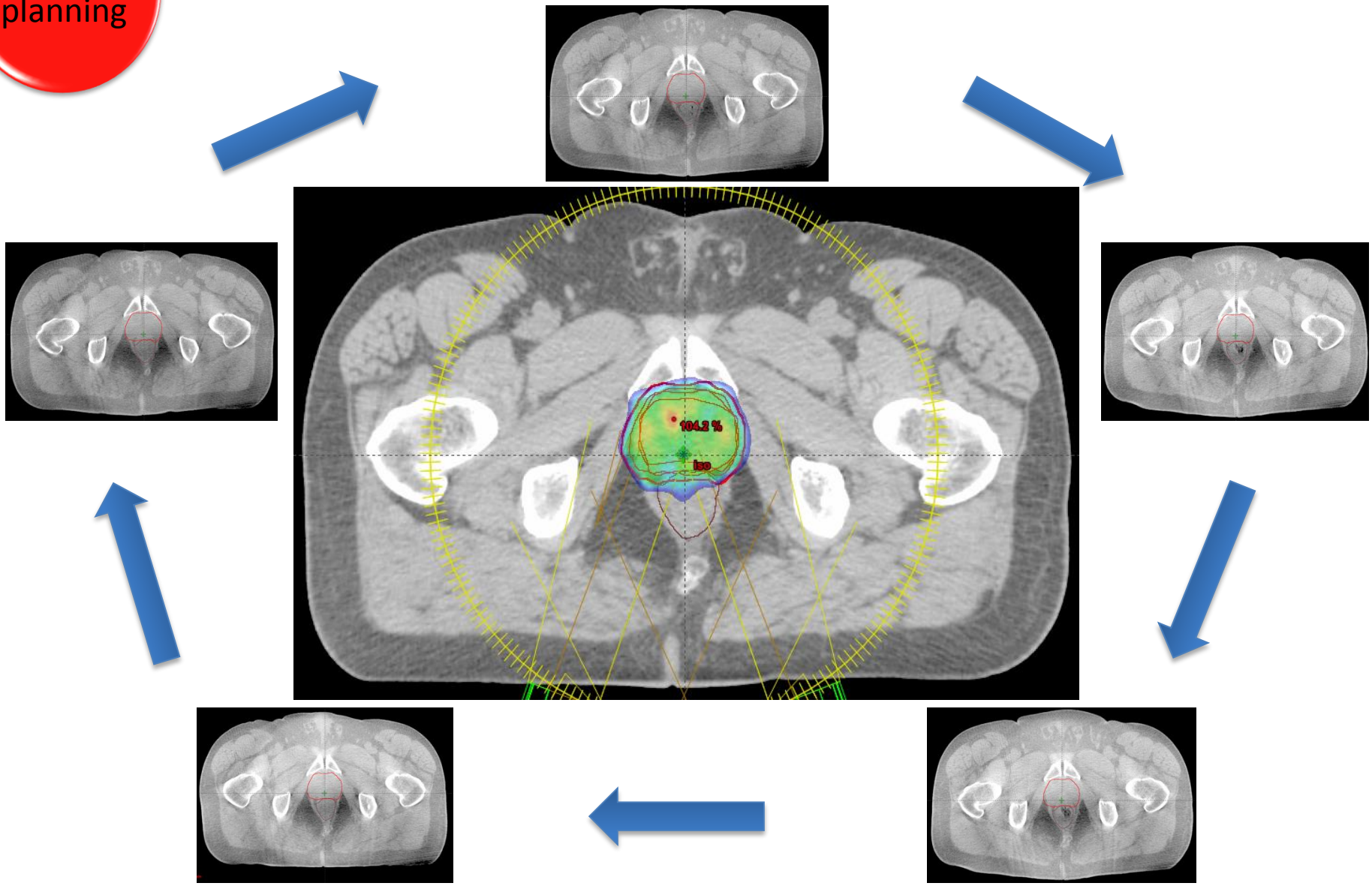
Adaptive planning

REPLANNING ON CBCT



Adaptive planning

REPLANNING ON CBCT



Adaptive planning

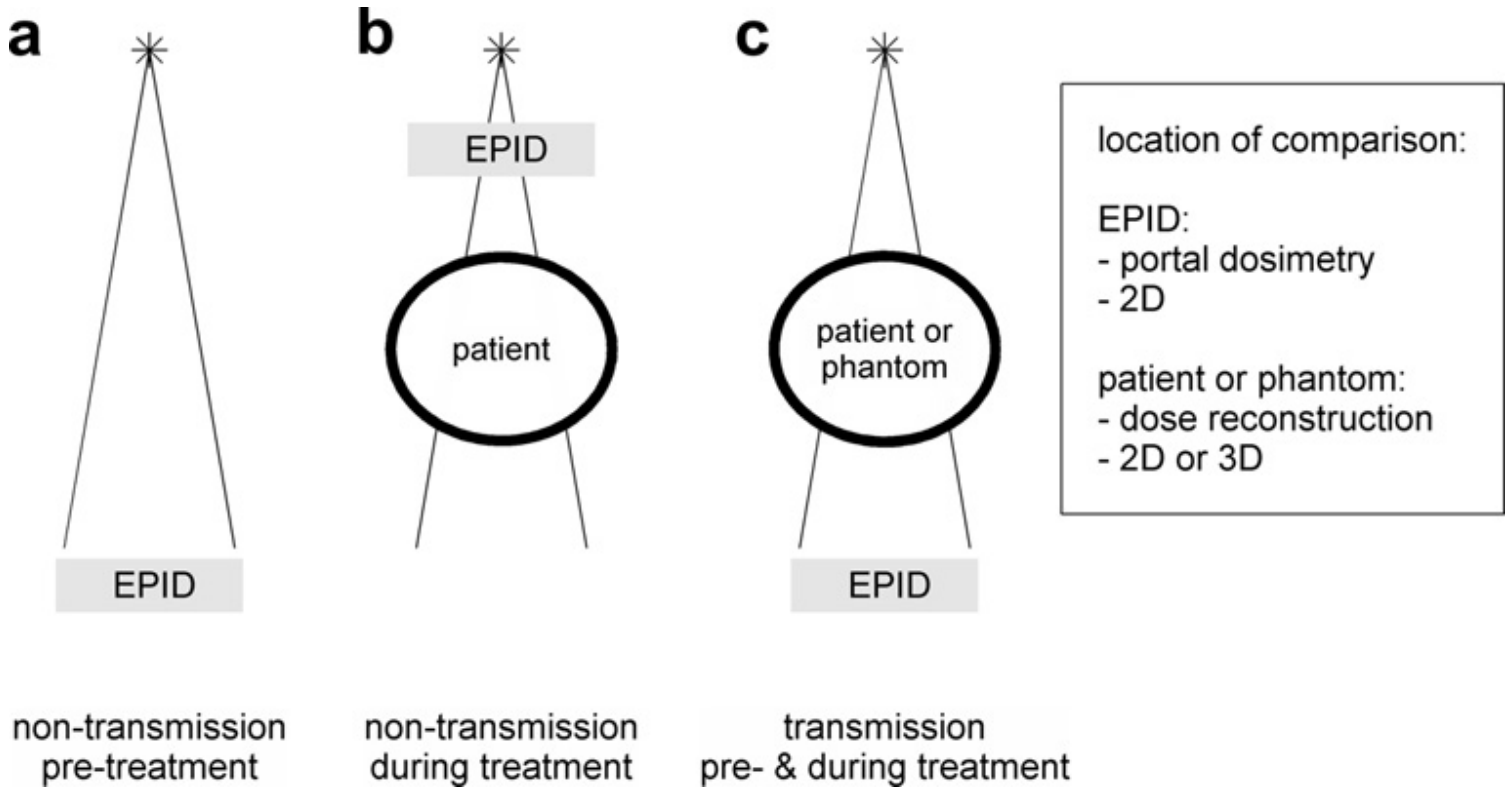
Replanning based on *in-vivo* dosimetry

Replanning methods based on the dose delivery variations detected with the in-vivo dosimetry performed by EPID

Adaptive planning

Replanning based on *in-vivo* dosimetry

Principles on which is based in vivo dosimetry by EPID



Generally the methods is based on the use of a back-projection algorithm to reconstruct a dose plan inside the patient

Adaptive planning

Replanning based on *in-vivo* dosimetry

2008

Radiotherapy &Oncology
European Society of Radiotherapy and Oncology

"patient errors are specially related to errors due to **changes** in the patient's positioning or **anatomy** from the situation at planning"

A literature review of electronic portal imaging for radiotherapy dosimetry
Wouter van Elmpt, Leah McDermott, Sebastiaan Nijsten, Markus Wendling, Philippe Lambin, Ben Mijnheer.

Adaptive planning

Replanning based on *in-vivo* dosimetry

Potential errors	Pre-treatment verification				Treatment verification			
	2D/3D	2D		3D	2D			3D
	No phantom	Behind phantom	Inside phantom	Inside phantom	Before patient	Behind patient	Inside patient	Inside patient
Gantry angle	No	Possible	Possible	Possible	No	Possible	Possible	Possible
Table arm obstruction	No	No	No	No	No	Yes	Yes	Yes
Obstructions from immobilisation devices	No	No	No	No	No	Yes	Yes	Yes
Anatomical changes in patient since planning CT	No	No	No	No	No	Yes	Yes	Yes
Anatomical movements during treatment	No	No	No	No	No	Yes	Yes	Yes
Wrong patient during treatment	No	No	No	No	No	Yes	Yes	Yes
Under/over-dose to volumes of interest	No	No	No	No	No	No	Single plane	Yes
Dose distribution in patient during treatment	No	No	No	No	No	No	Single plane	Yes

Wouter van Elmpt et al.
Radiotherapy and Oncology, 2008

Adaptive planning

Replanning based on *in-vivo* dosimetry

2009

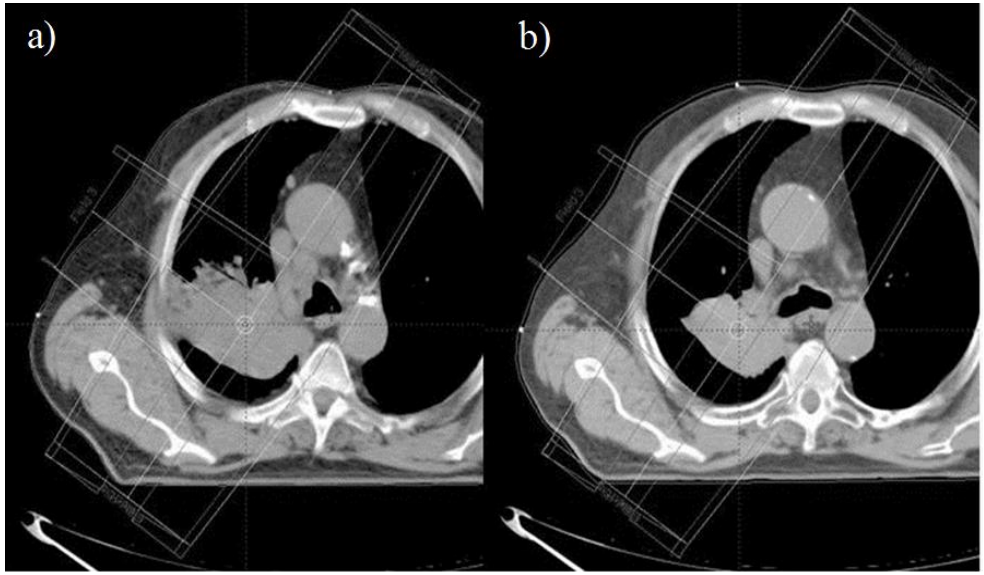
Medical Physics
The International Journal of Medical Physics Research and Practice

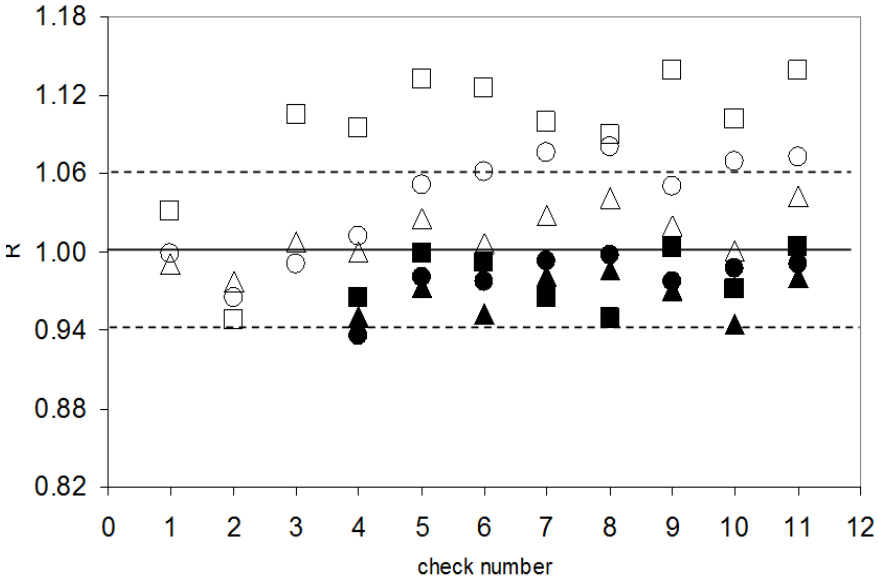
Integration between in vivo dosimetry and image guided radiotherapy for lung tumors

Angelo Piermattei, Savino Cilla, Luca Grimaldi, Domenico Sabatino, Andrea Fidanzio, et al.

Adaptive planning

Replanning based on *in-vivo* dosimetry





"In this work, a patient that showed for all beams *D*iso values outside the tolerance level, **new CT scan were commissioned for an adaptive plan**. …….the DGRT can be well integrated withthe IGRT"

Integration between in vivo dosimetry and image guided radiotherapy for lung tumors
Piermattei A, Cilla S, Fidanzio A, et al. Med. Phys 2009

Adaptive planning

PLAN LIBRARY

Plan library elaboration for choosing the **"plan of the day"** that takes in to account the different filling variations of the PTV surrounding structures, as bladder and rectum in the pelvis, for instance, or different extent of motion.

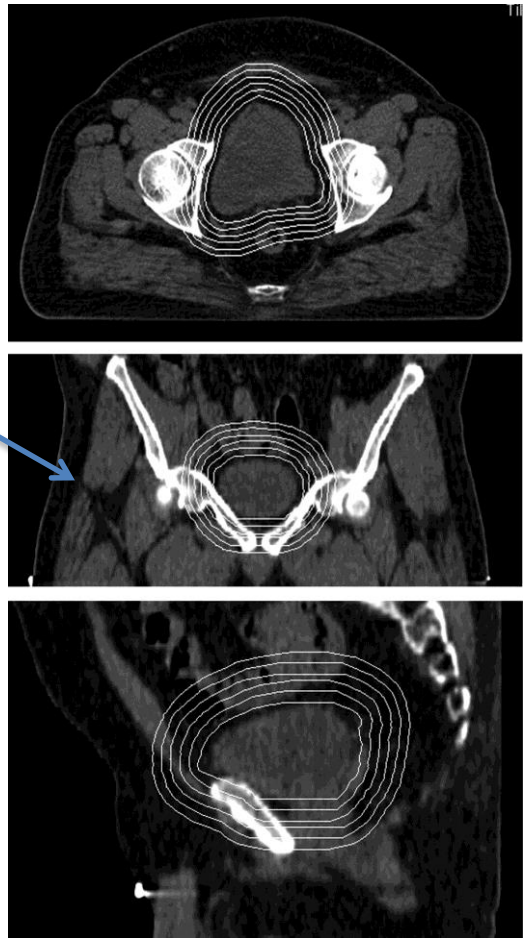
- **Different margins**
- **Different position**

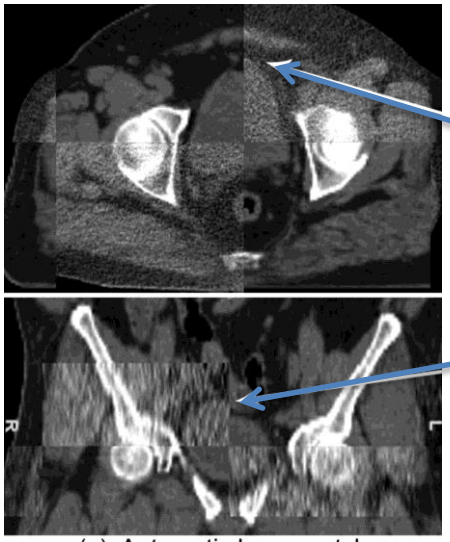
Adaptive planning

PLAN LIBRARY

Different margins

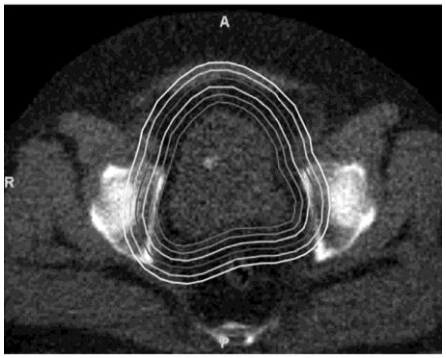
Plan with 6 different isotropic margin





(a) Automatic bone match

Bladder not matching after bone matching



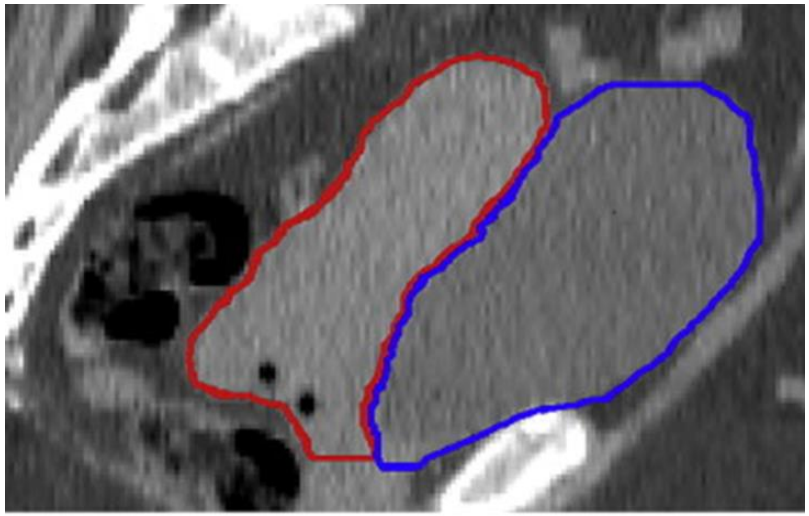
(b) Bladder match: Bladder moved to fit into 5mm PTV

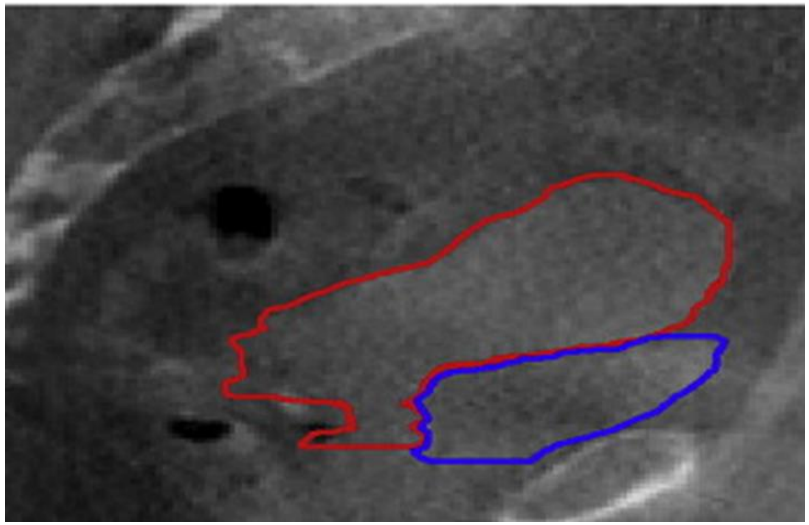
'Plan of the day' adaptive radiotherapy for bladder cancer using helical tomotherapy.
Murthy V, Master Z, Adurkar P, Mallick I, et al.
Radiother. Oncol. 2011 Apr;99(1):55-60

Adaptive planning

PLAN LIBRARY

Different position





A library with plans that consider different daily PTV and organs position

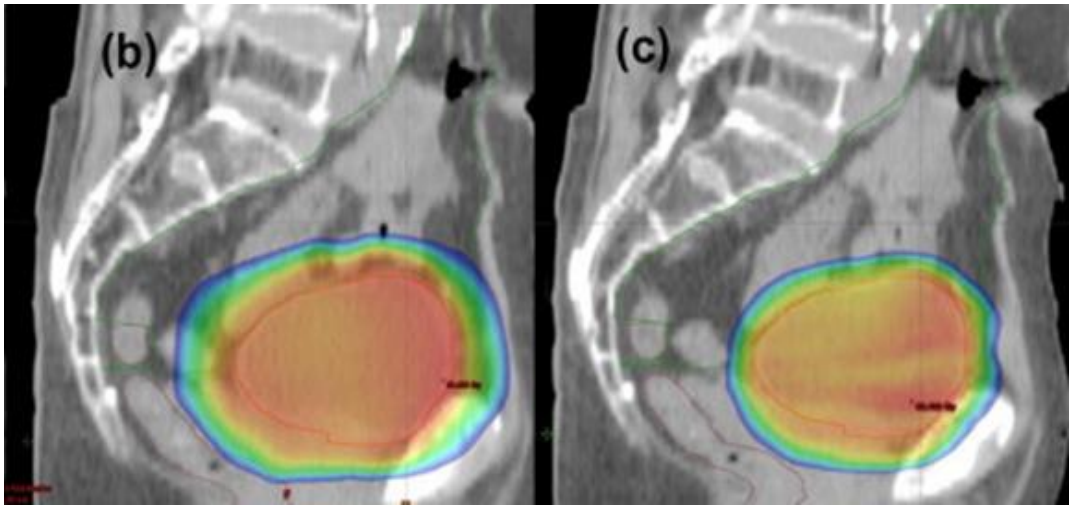
Adaptive planning

Bladder cancer treatment

Plan selection *Vs.* ***Daily on line re-optimization***

Plan library: 3 plans with 3 different Bladder size (small, medium, large)

CBCT is registered in deformable way on the planning CT and ricalculated

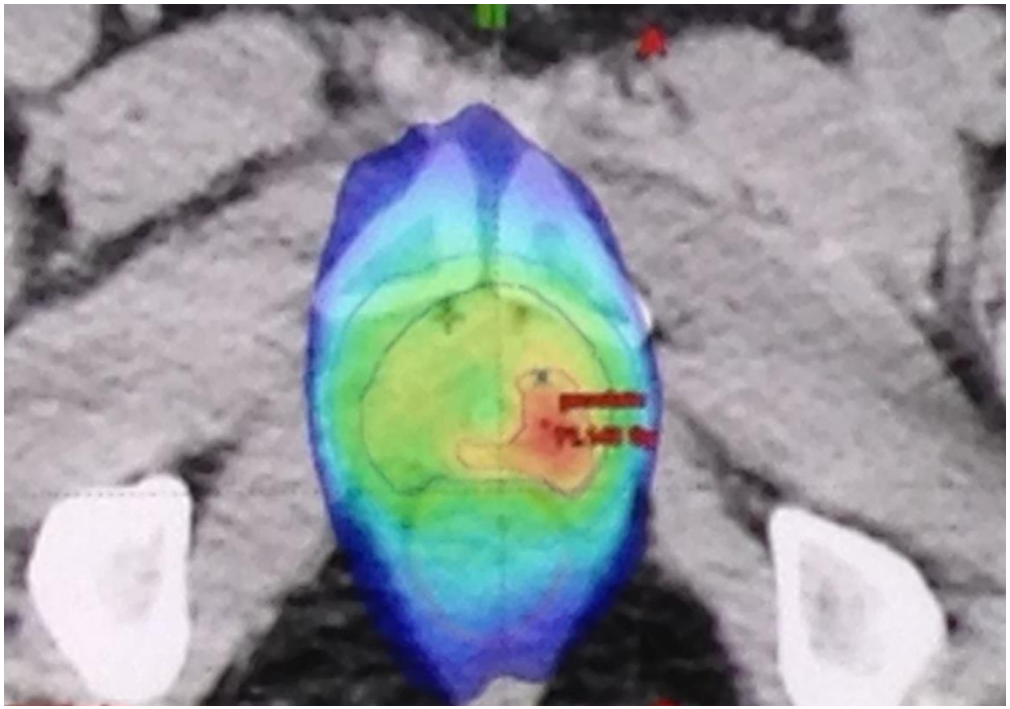


Adaptive plan selection vs. re-optimization in radiotherapy for bladder cancer: a dpse accumulation comparison
A Vestergaard, LP Muren, J Søndergaard et al.
Aarhus University Hospital Radiother. and Oncol . 2013

Adaptive planning

DOSE PAINTING

Dose Painting is a **biologically adaptive radiation therapy** approach, that consists in an **increase of dose** in one or more sub-volumes identified by **functional imaging**



Adaptive planning

DOSE PAINTING

18F-choline PET, IMRT dose distribution and dose prescription in accordance with the TCP model

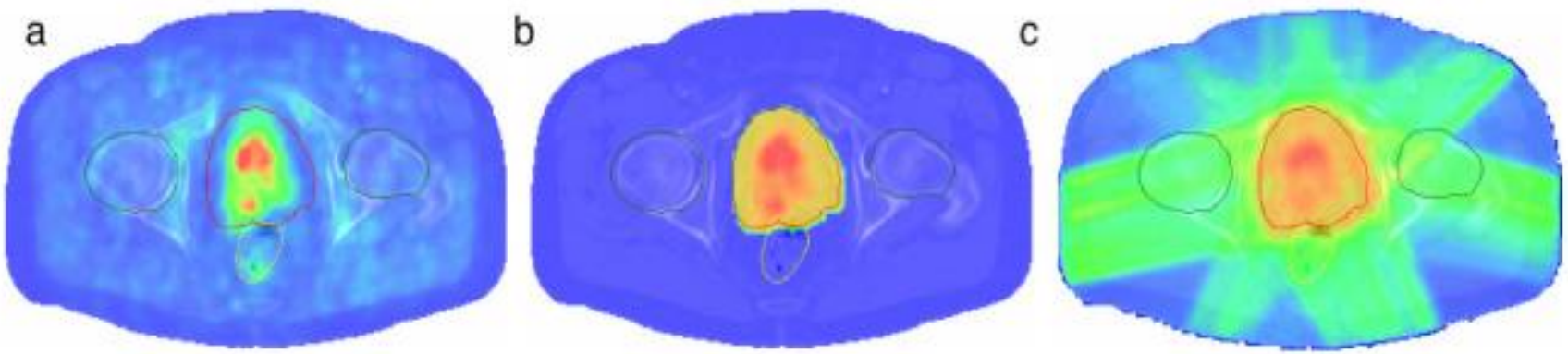


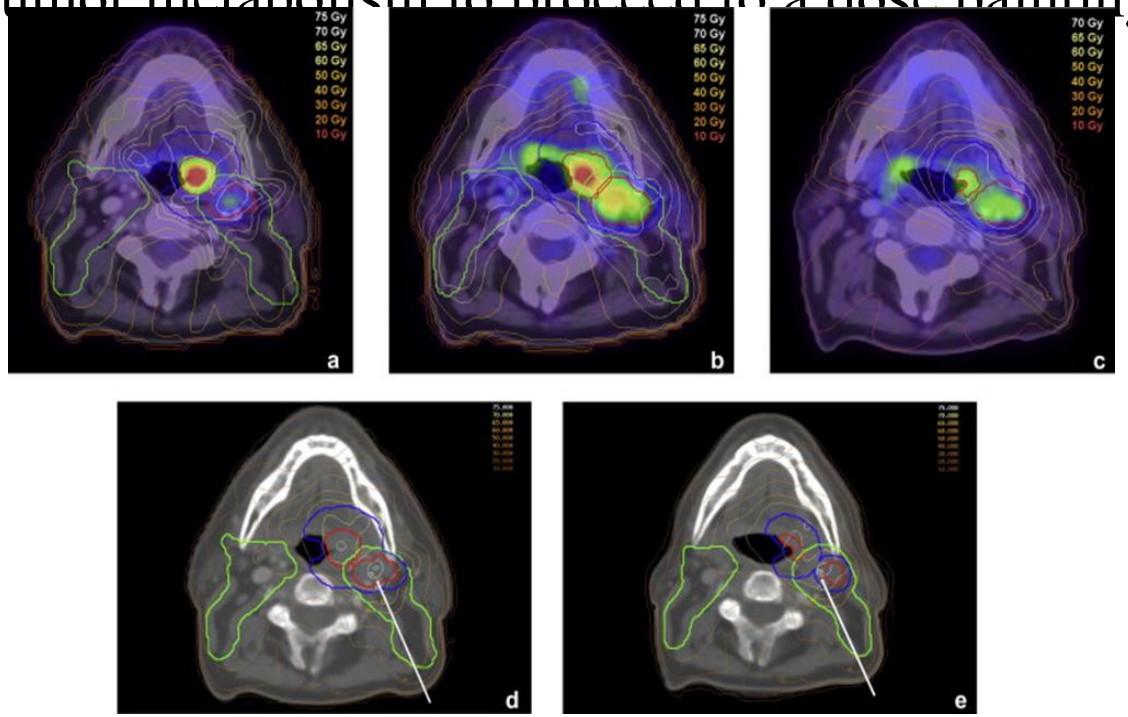
Fig. 5. a) ^{18}F-choline PET activity signal in a transversal slice, which is mapped to the radiobiological parameters γ and ρ. b) Voxelwise dose prescription according to the TCP model in the same slice. c) Resulting dose distribution after optimization with DMCO. The red line denotes the PTV.

Feasibility of TCP-based dose painting by numbers applied to a prostate case with (18)F-choline PET imaging.
Thomas Dirscherl, Mark Rickhey, Ludwig Bogner
Z. Med. Phys. 22 (2012) 48–57

Adaptive planning

DOSE PAINTING

Use of images of planned PET-CT to detect the variation of
the tumor metabolism to proceed to a dose painting plan

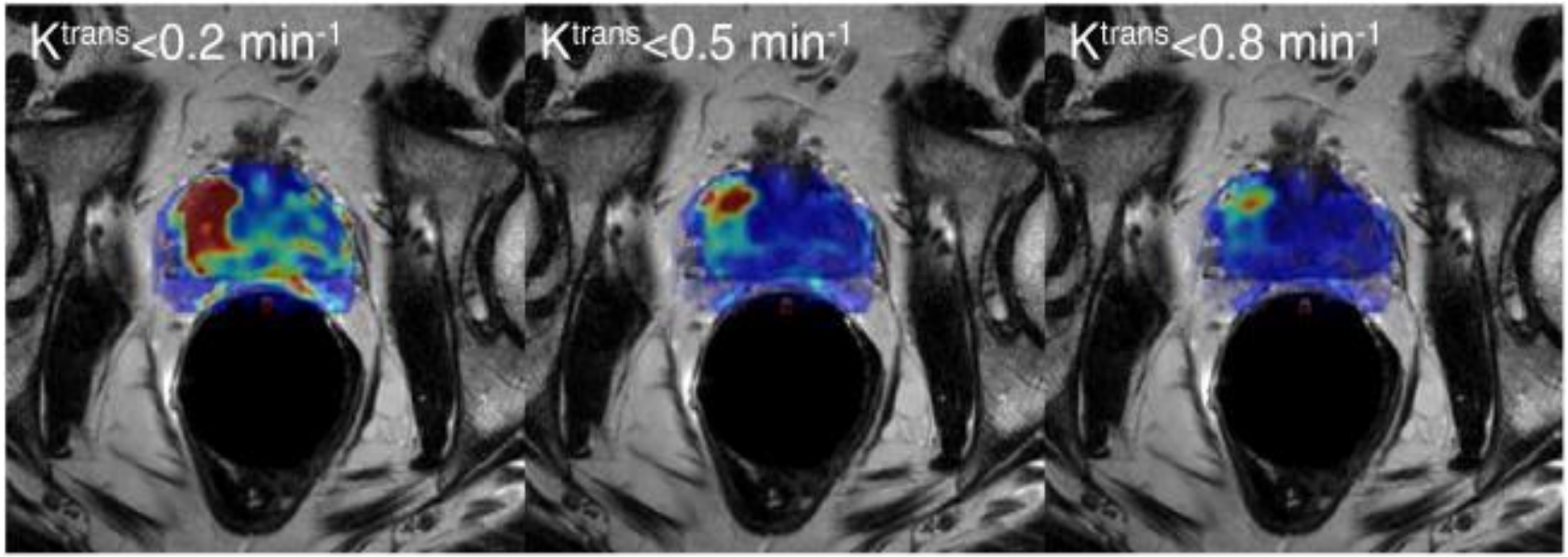


Three-phase adaptive dose-painting-by-numbers for head-and-neck cancer: initial results of the phase I clinical trial
Dieter Berwoutsemail, Luiza A.M. Olteanu, Indira Madani, et al.
Radiotherapy & Oncology
Volume 107, Issue 3 , Pages 310-316, June 2013

Adaptive planning

DOSE PAINTING

"Diffusion-weighted MRI reflects the cell density of tissue and thus may indicate regions with a higher tumor load"



Functional MRI for radiotherapy dose painting
Uulke A. van der Heidea, Antonetta C. Houweling,
Greetje Groenendaal, Regina G.H. Beets-Tan, Philippe Lambin
Magnetic Resonance Imaging 30 (2012) 1216–1223

Adaptive planning

Recommended ESTRO Core Curriculum for RTTs - 3°edition

"the RTT perspective"

REPLANNING ON A NEW CT

REPLANNING ON CBCT

In-vivo DOSIMETRY

PLAN LIBRARY

DOSE PAINTING

M.A. Coffey, L. Mullaney, A. Bojen, A.Vaandering, G. Vandevelde.
Radiother Oncol. 2012 Apr;

Adaptive planning

CONCLUSIONS

- Adaptive planning is a fundamental "tool" to perform adaptive RT
- There is an increasing number of methodologies and so complexity
- Changing of workflow and considerable increase of workload
- The perspective of an RTT with current skills is to be involved in these procedures and must be able to manage this development within the multi-professional team

Adaptive planning

CONCLUSIONS

- Adaptive planning is a fundamental "tool" to perform adaptive RT
- There is an increasing number of methodologies and so complexity
- Changing of workflow and considerable increase of workload
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Thank you for your attention