



To promote excellency in patient care and innovative proton treatment

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What have commercial systems to offer-what do we need

Discuss what is currently commercially available to support 4D treatment planning (for scanned proton therapy)

And what would be necessary from a clinical (medical physicist) prospective

Disclaimer: I am not an expert.

We have never treated a 4D- patient (yet)

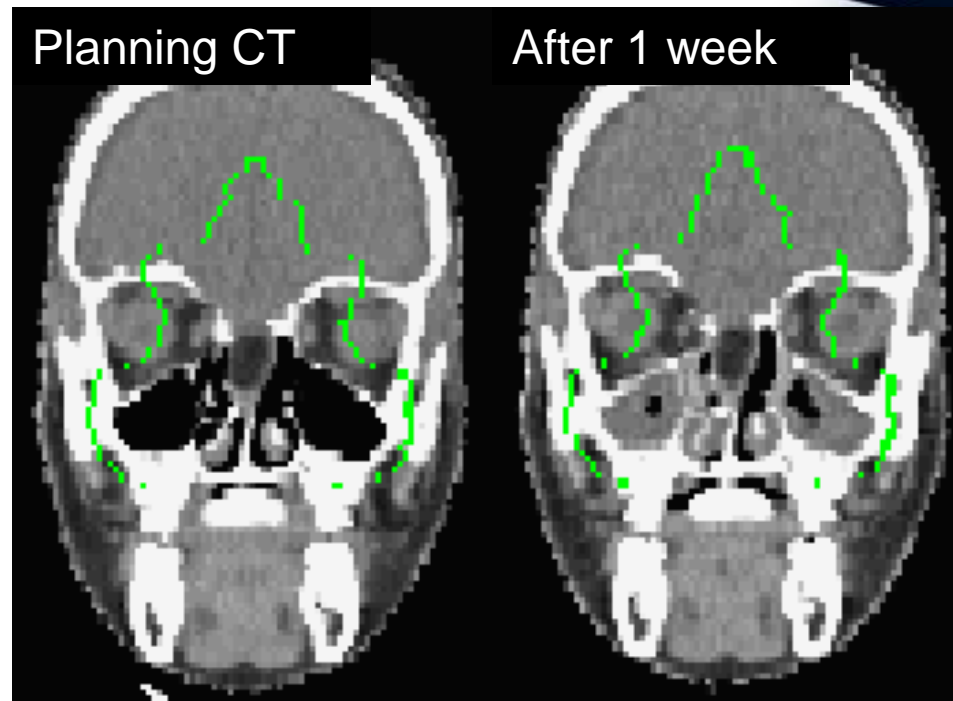
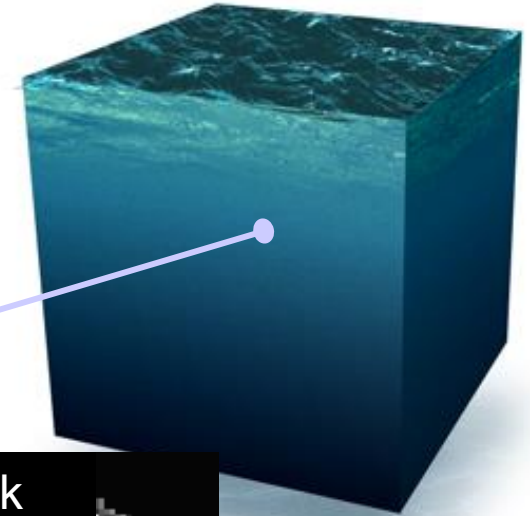
The organizers asked:

Discuss what is currently commercially available to support 4D treatment planning (for scanned proton therapy)



What a clinical medical physicist would like (personal opinion)

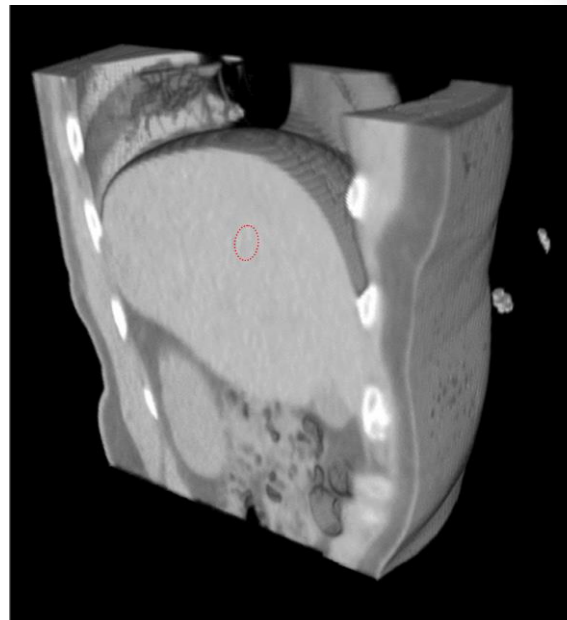
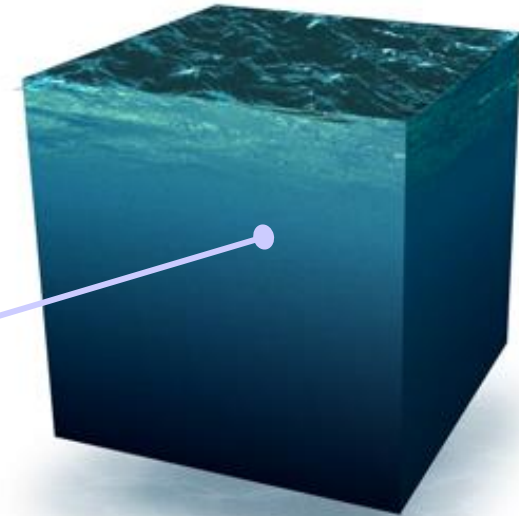
-like to treat static target in a well defined and constant (over time) density (no Range, no Set-up errors)



Inter-fraction changes

What a clinical medical physicist would like (personal opinion)

-like to treat static target in a well defined and constant (over time) density (no Range errors)



Intra-fraction changes

What a clinical medical physicist would like

Practical-Simplistic view

1. Calculate a 3D plan on the CT that is the best representation of the treatment anatomy (each treatment day);
2. Evaluate the quality of the plan in the delivery conditions
3. Change/modify the plan such as to reduce/minimize the difference between the calculated and the delivered plan



-what we need
-what is commercially available

Challenges (1)

(1) Calculate a 3D plan on the CT that is the best representation of the anatomy on (each) treatment day;



how am I going to treat the patient?
Breath- hold
free -breathing
gating

-where am I defining the volumes?

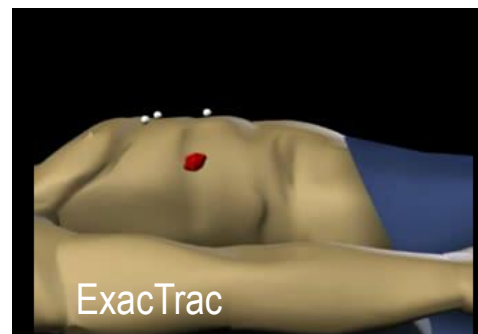
-which phase
-4D CT (possibly 4D-MRI)
-which CT (MIP, average CT,...)

... **Re-scanning**
Free breathing

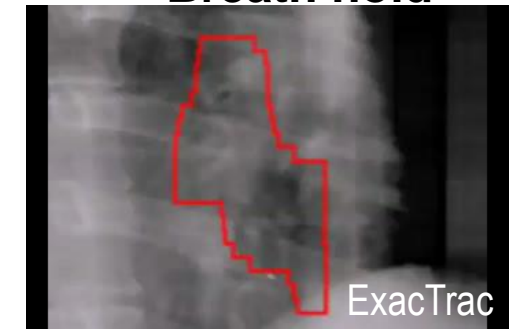


Motion mitigation approaches

Gating



Breath hold

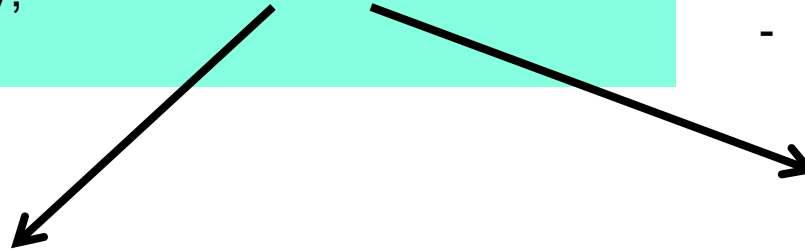


courtesy of G Fattori

What is commercially available (TPS)

(1) Calculate a plan on the CT that is the best representation of the anatomy on (each) treatment day;

- (a) Image manipulation/handling:
- Import of 4D CT
 - average CT;
 - Maximum intensity projection CT (MIP)



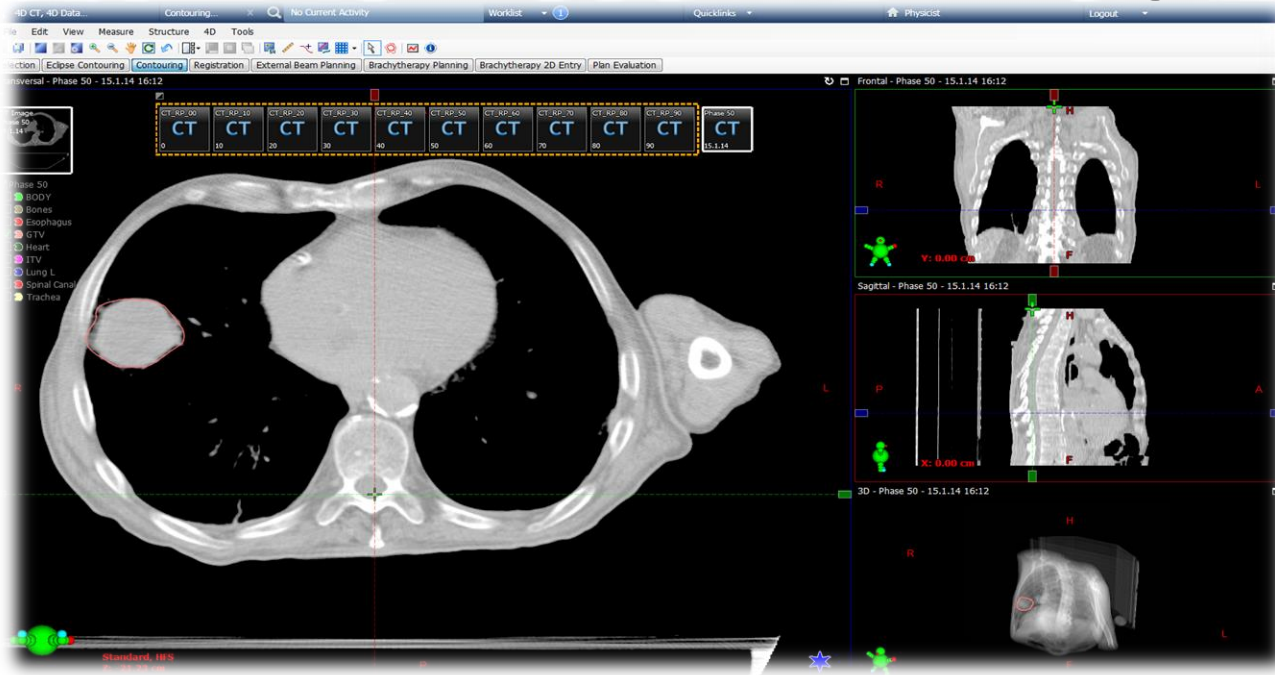
(b) Deformable Registration (DIR) tools to help delineate the volumes (and to propagate the volumes to different phases)

Monaco®



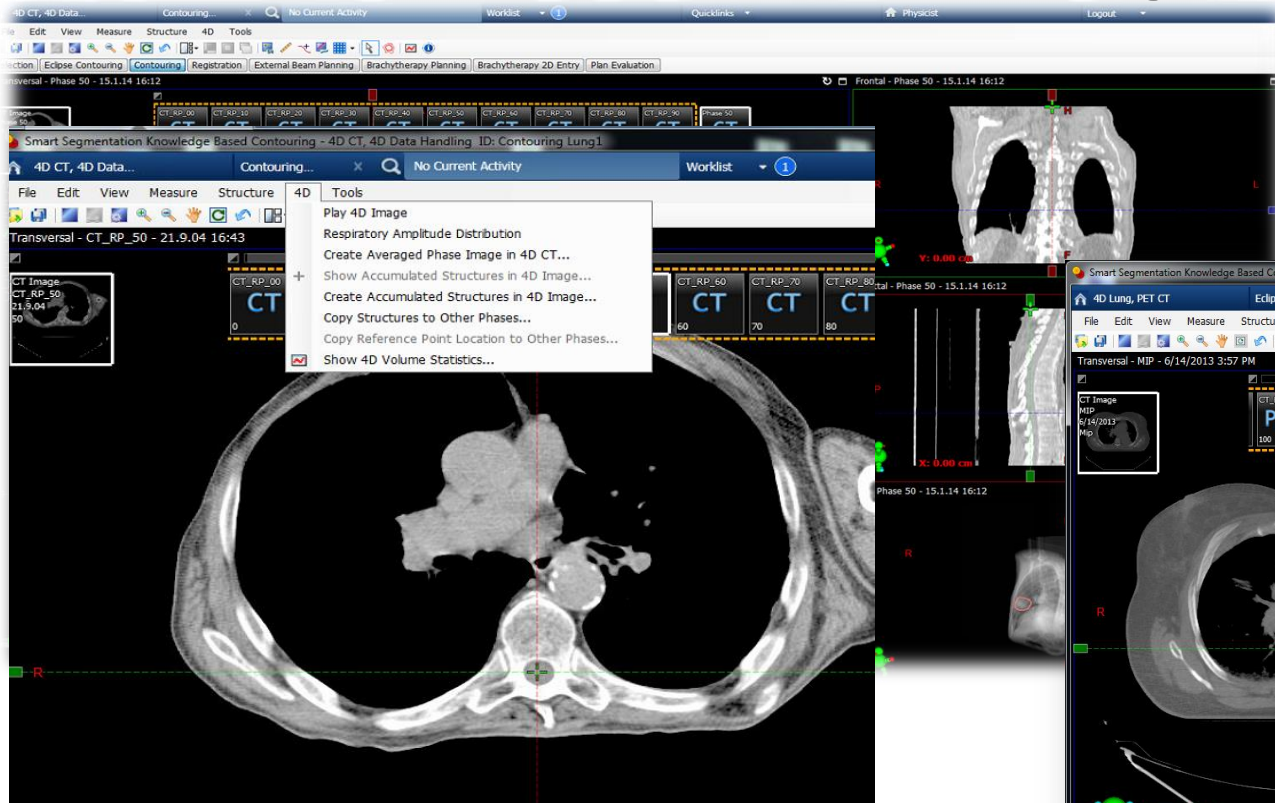
What is commercially available

4D Data Handling Tools

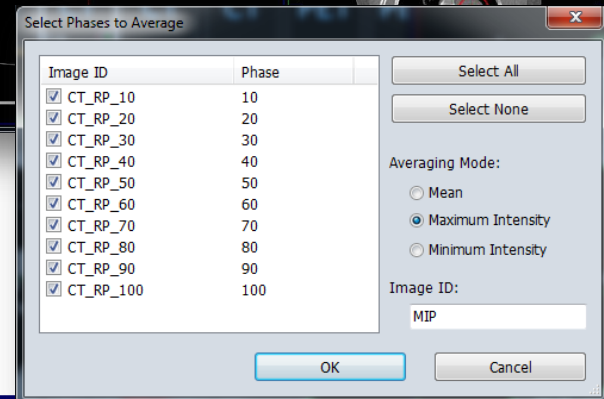
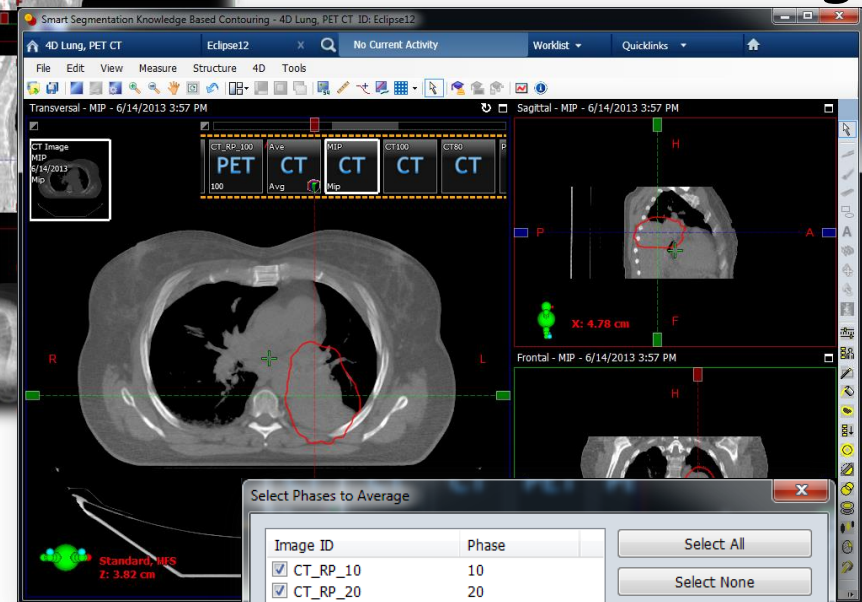


What is commercially available

4D Data Handling Tools



Generation of
MIP, minIP, average

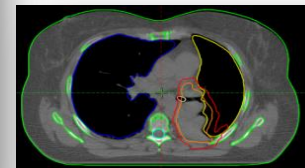
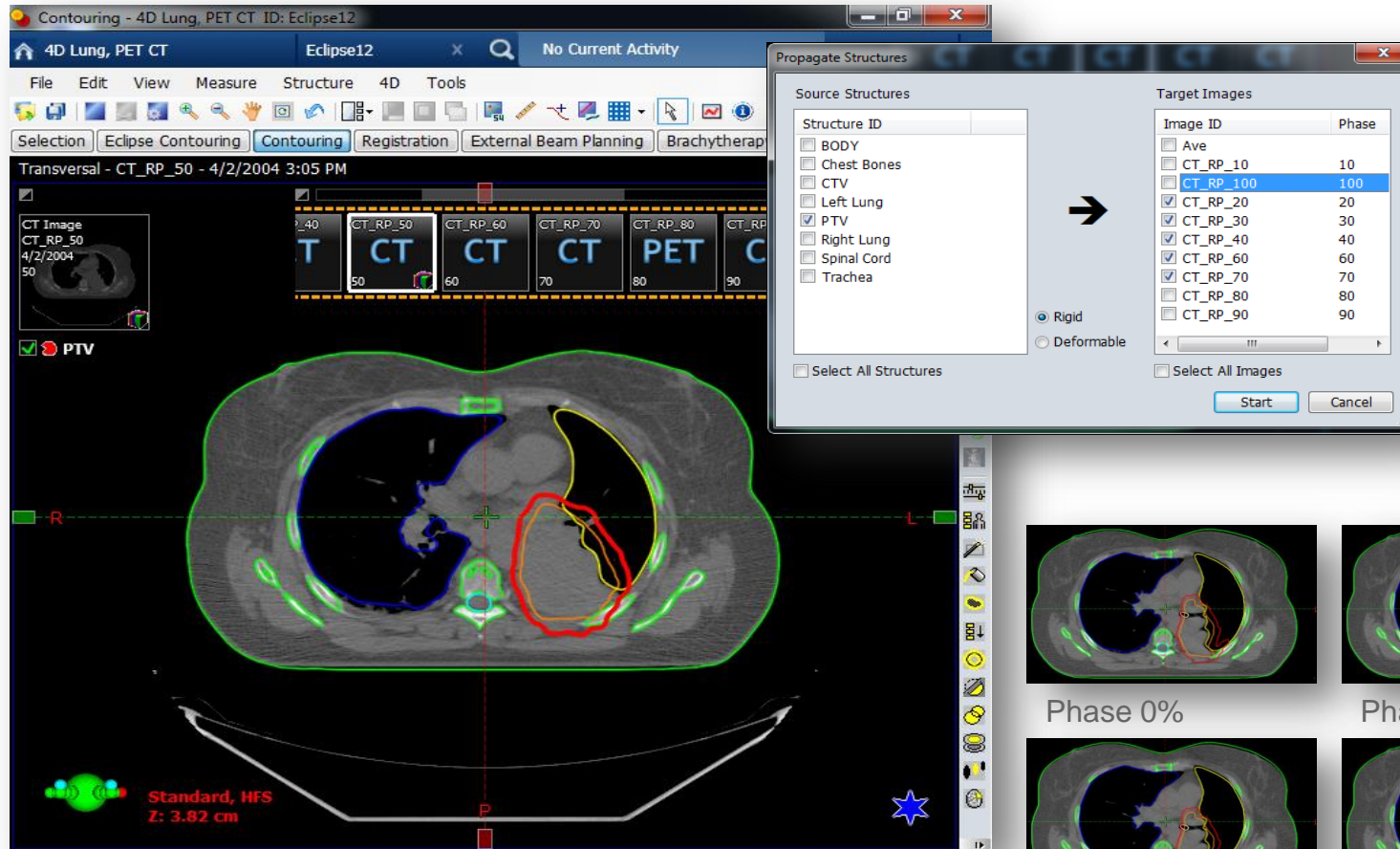


Generation of MIP, MinIP and AveIP
Play 4D image
Deformable Structure Propagation

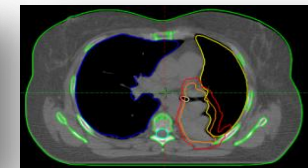
...

What is commercially available

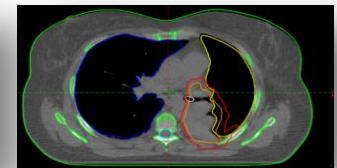
Deformable Structure Propagation



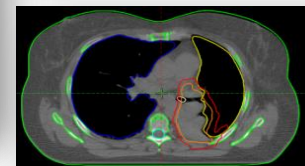
Phase 0%



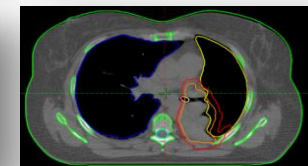
Phase 10%



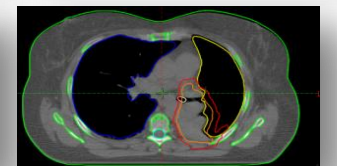
Phase 20%



Phase 30%



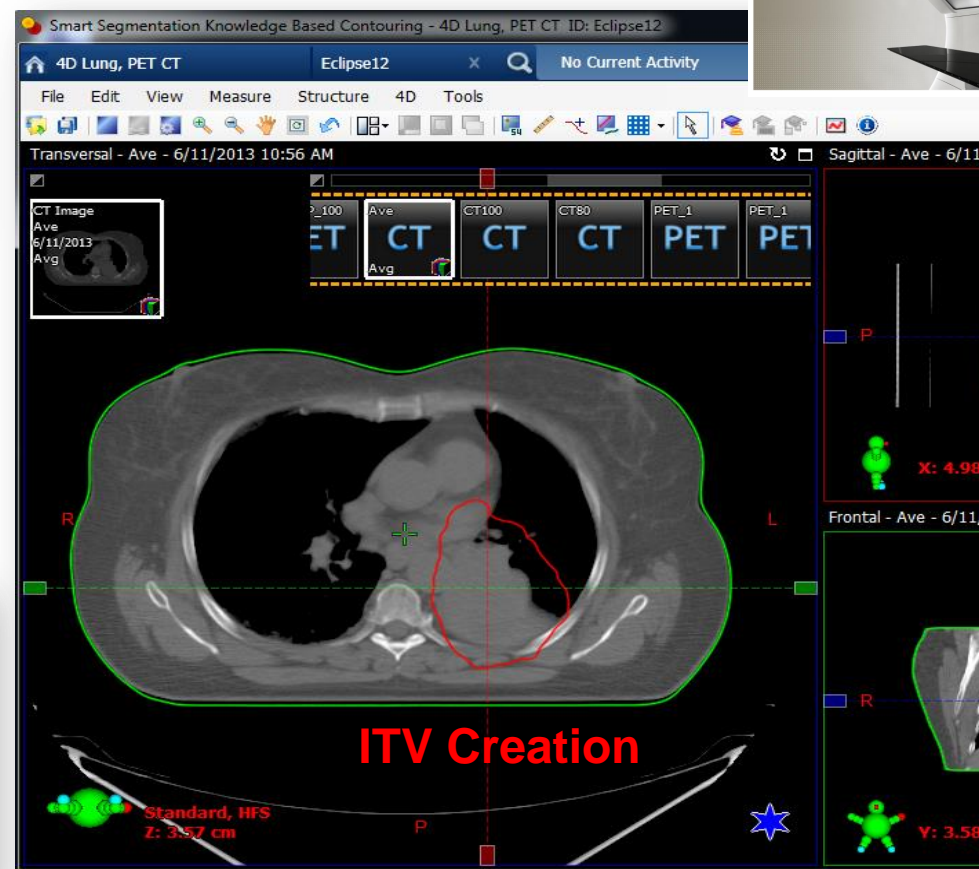
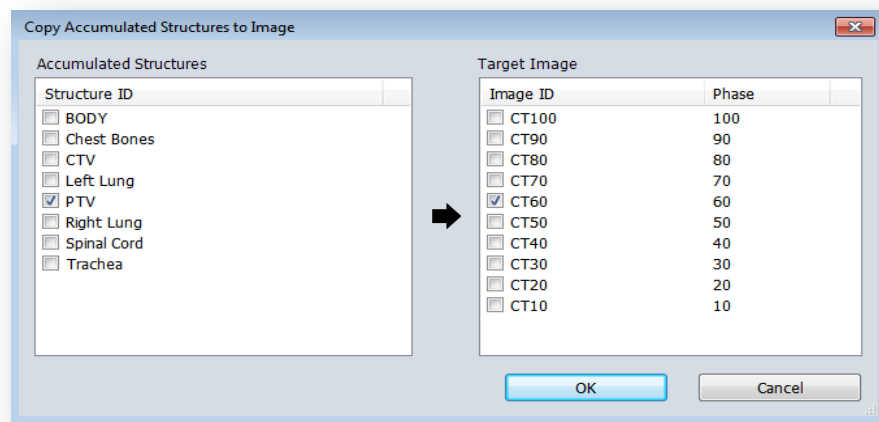
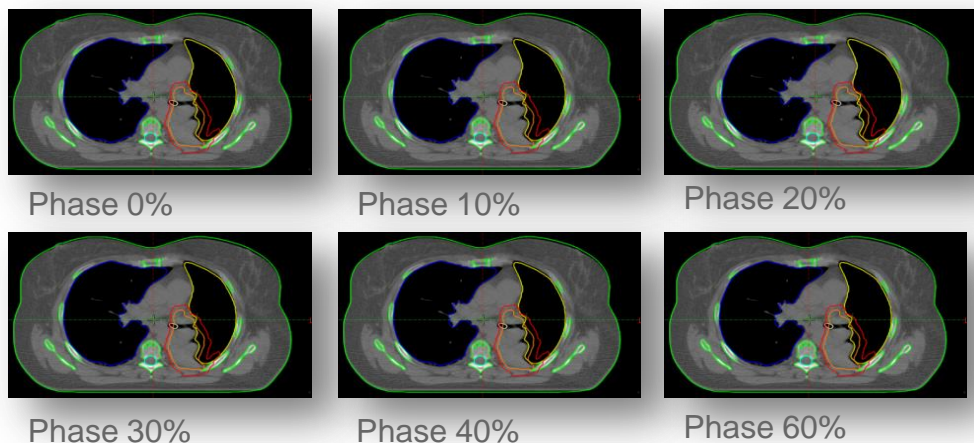
Phase 40%



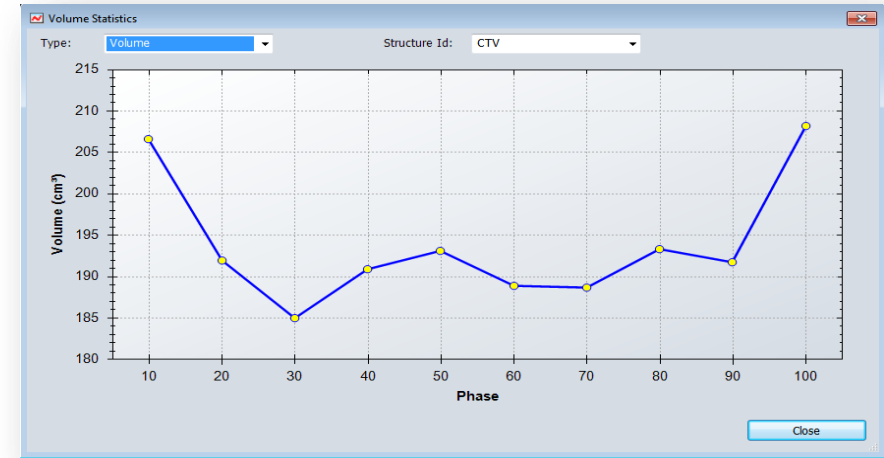
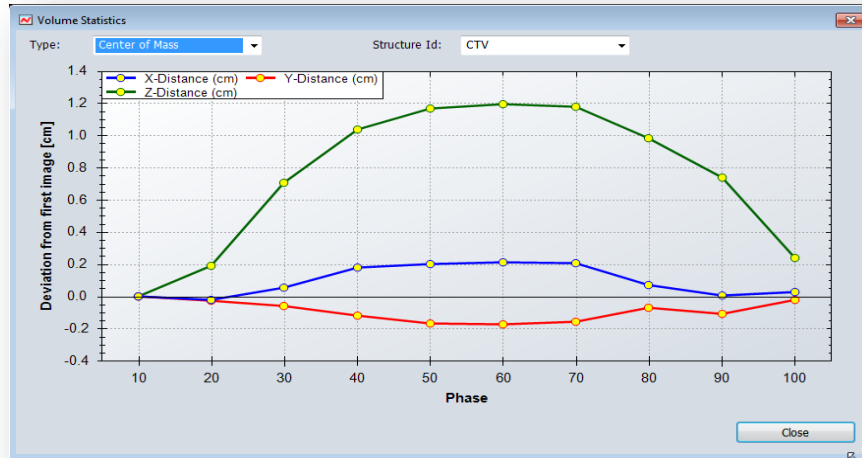
Phase 60%

What is commercially available

4D Structure Accumulation



4D Volume Statistics



DISPLACEMENT OF THE CENTER OF MASS

Helpful when making a decision on the respiratory phases to be included in gated treatments.

VOLUME VARIATION ANALYSIS

Useful when investigating the inter-phase tumor volume variation in gated treatment.

(2) Evaluate the quality of the plan under delivery conditions (including dynamic)

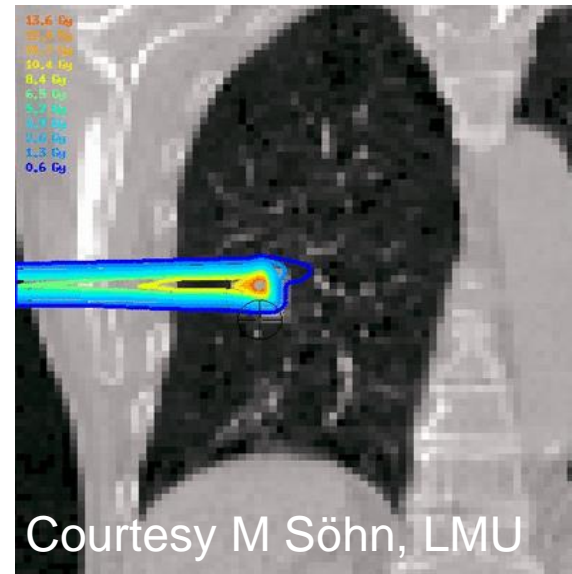


What do we need: 4D dose evaluation tool:

4D-dose calculation: Re-calculate the initial dose distribution considering the breathing motion and the delivery pattern (position of pencil beam vs the target position vs the heterogeneity)

How can we control the breathing pattern?

- Free breathing → motion extracted from 4D-CT(MRI) with a different starting phase
- True for every day? weekly control 4D-MRI/CT?

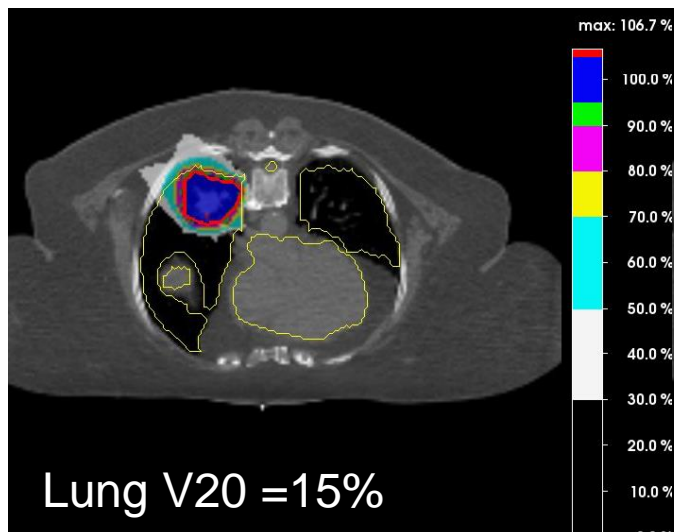


(2) Evaluate the quality of the plan under delivery conditions (breathing pattern)

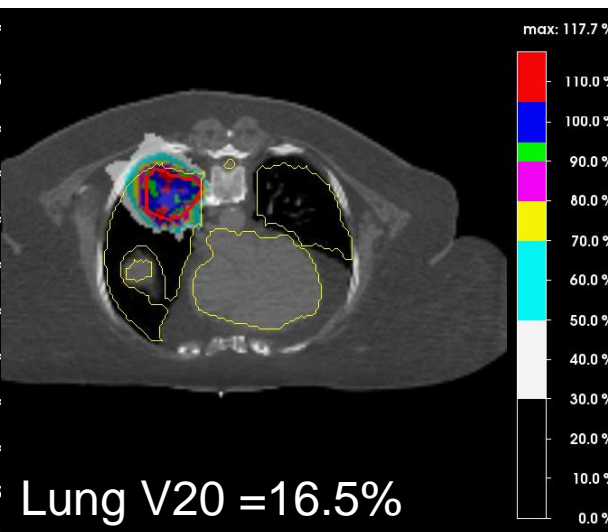
Why 4D dose evaluation is important:

Are detected differences clinically significant?

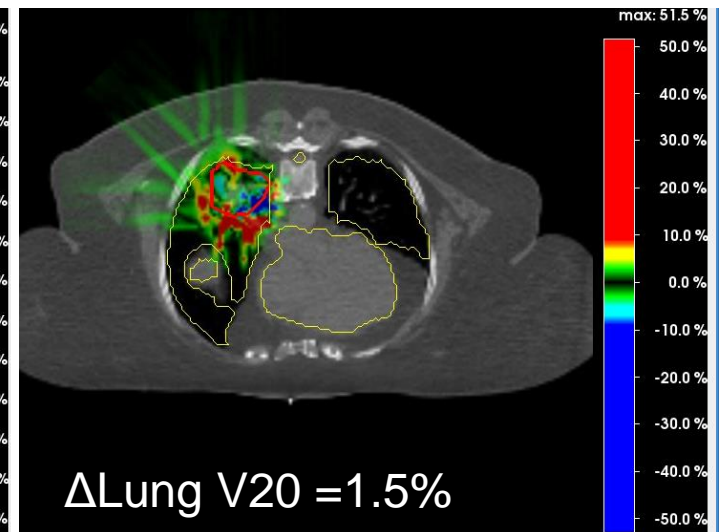
Static dose distribution



4D dose distribution



Difference dose distribution



What is commercially available (TPS)

(2) Evaluate the quality of the plan under delivery conditions (breathing pattern)



Re-calculation on different phases:

Assumes that the dose can be delivered within one breathing phase (4D dose calculation module not available.)

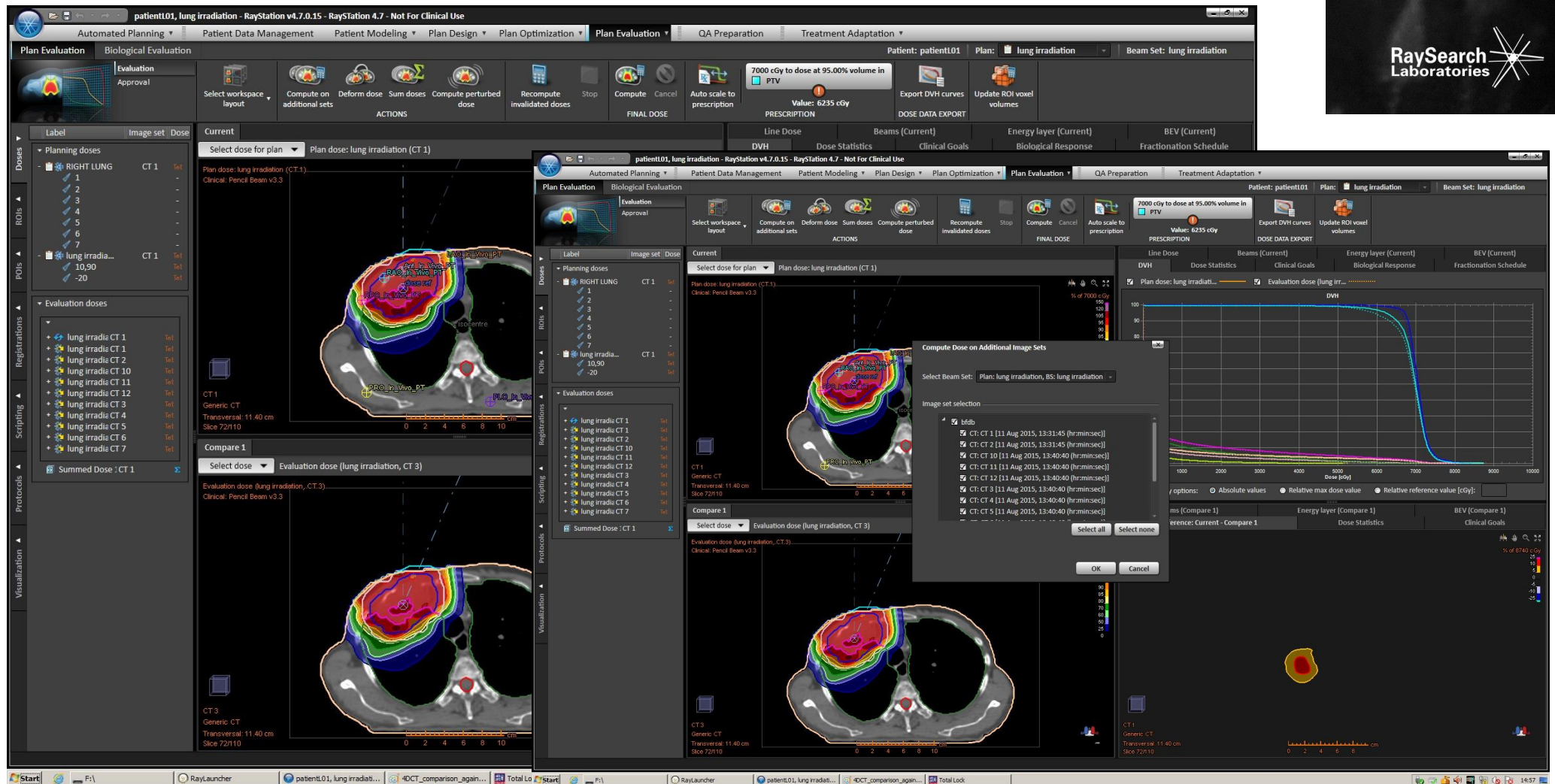


Good starting point but far from being a realistic representation of the delivered dose (for free-breathing and gating)



What is commercially available (TPS)

Recalculation on different phases

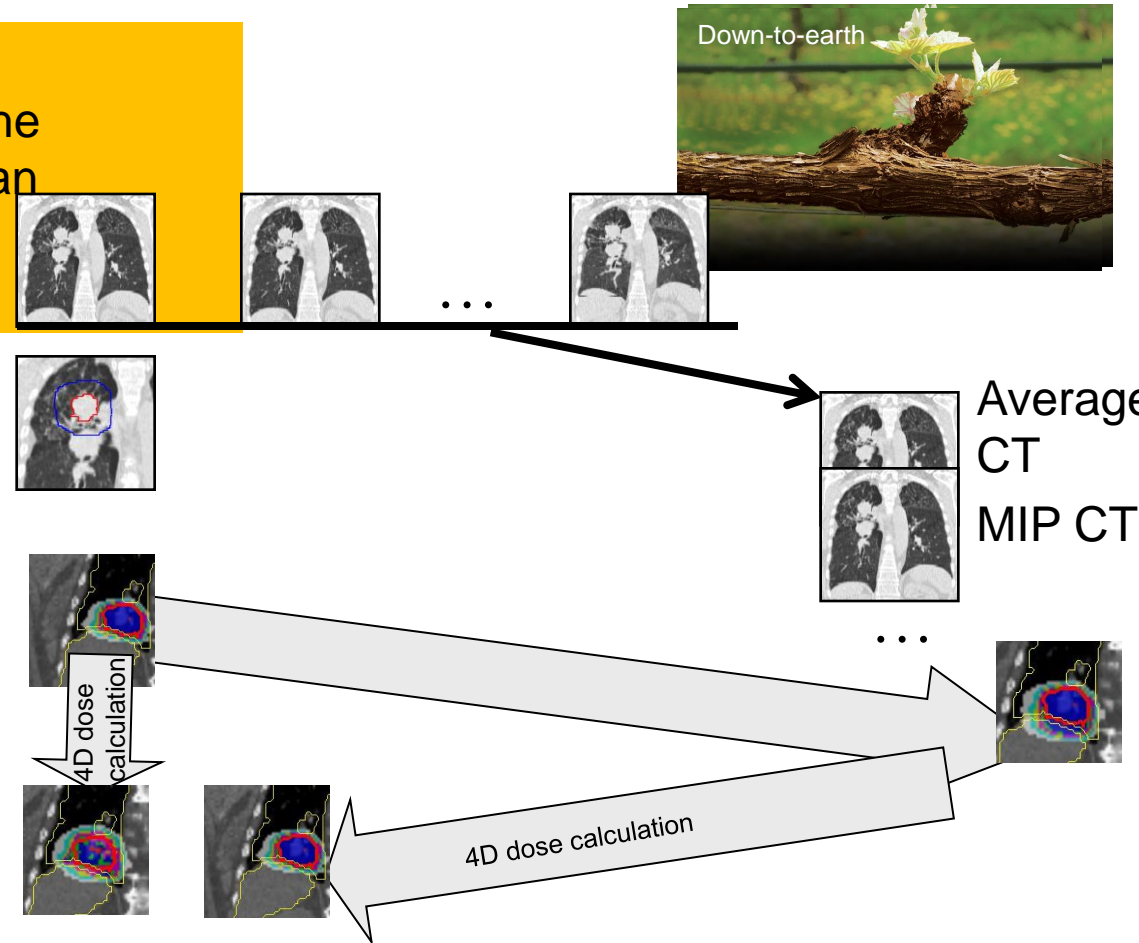
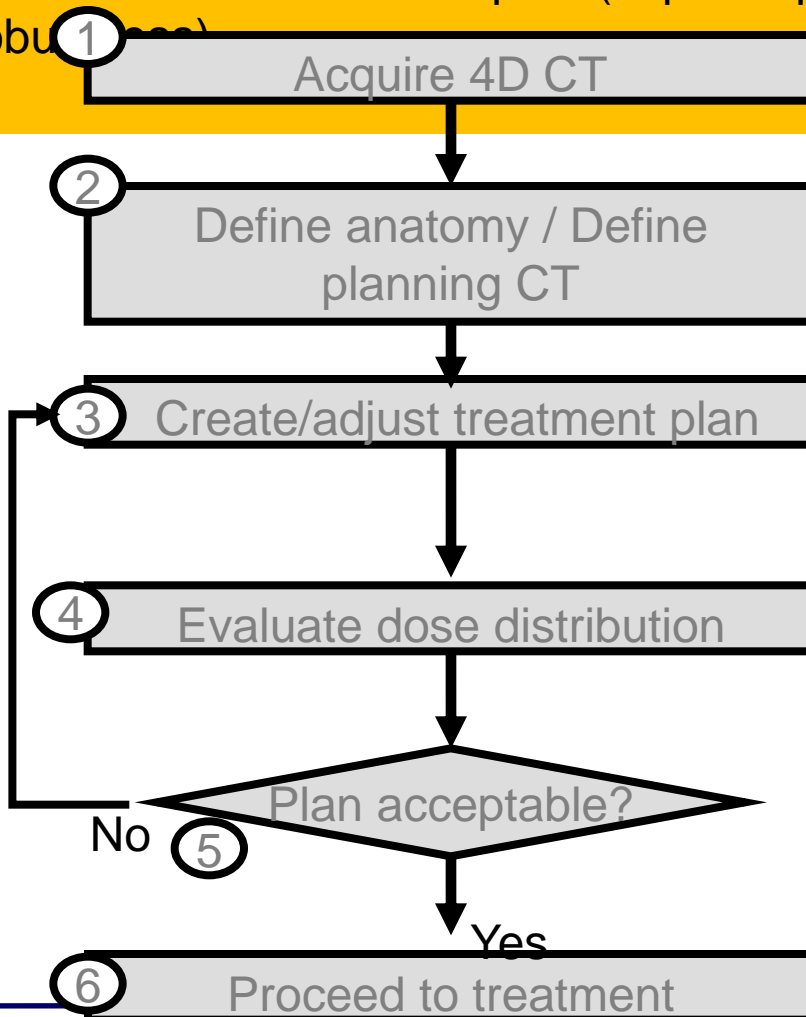


(3) Change/modify the plan such as to reduce/minimize the difference between the calculated and delivered plan (improve plan robustness)



Challenges (3)

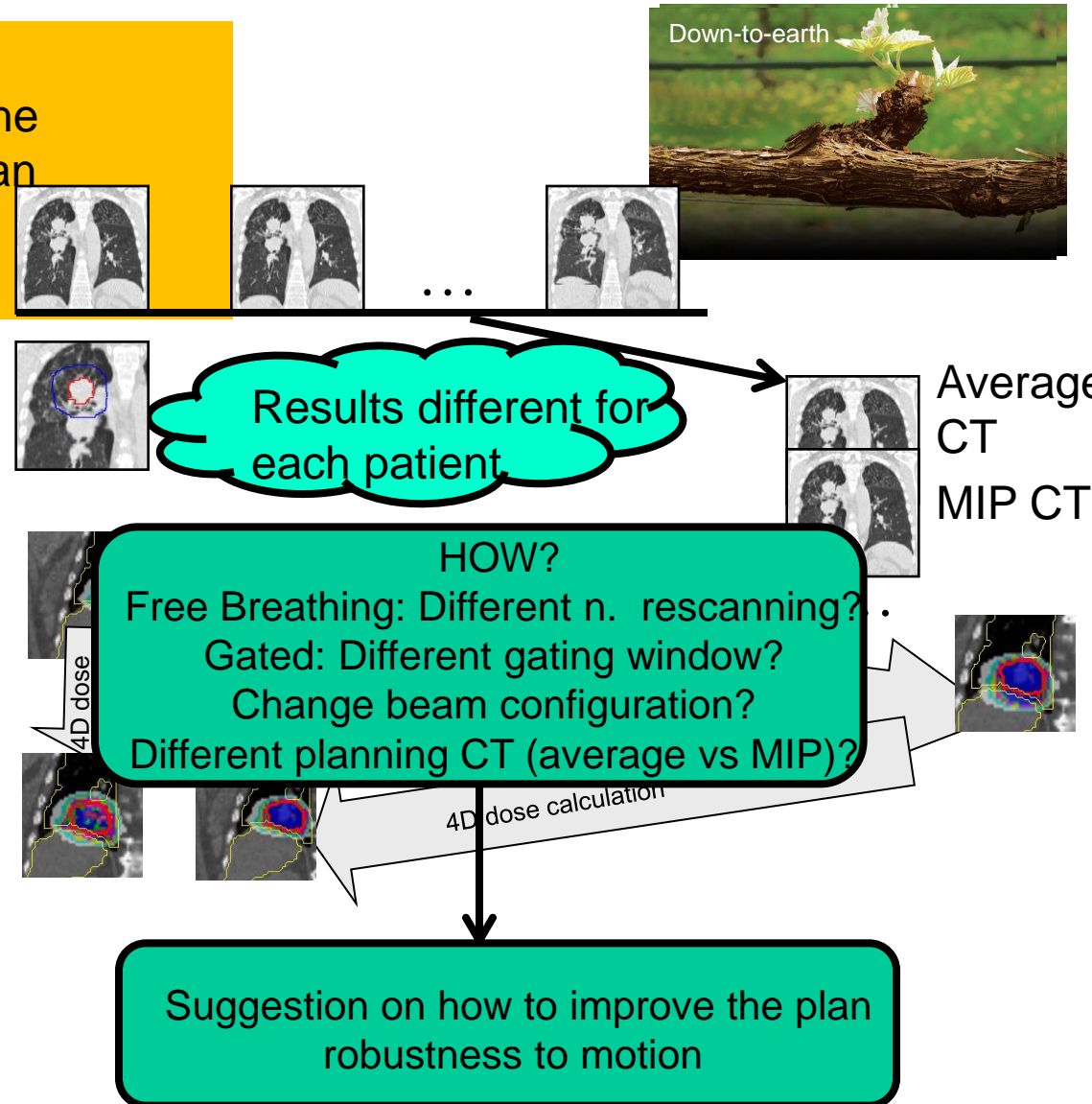
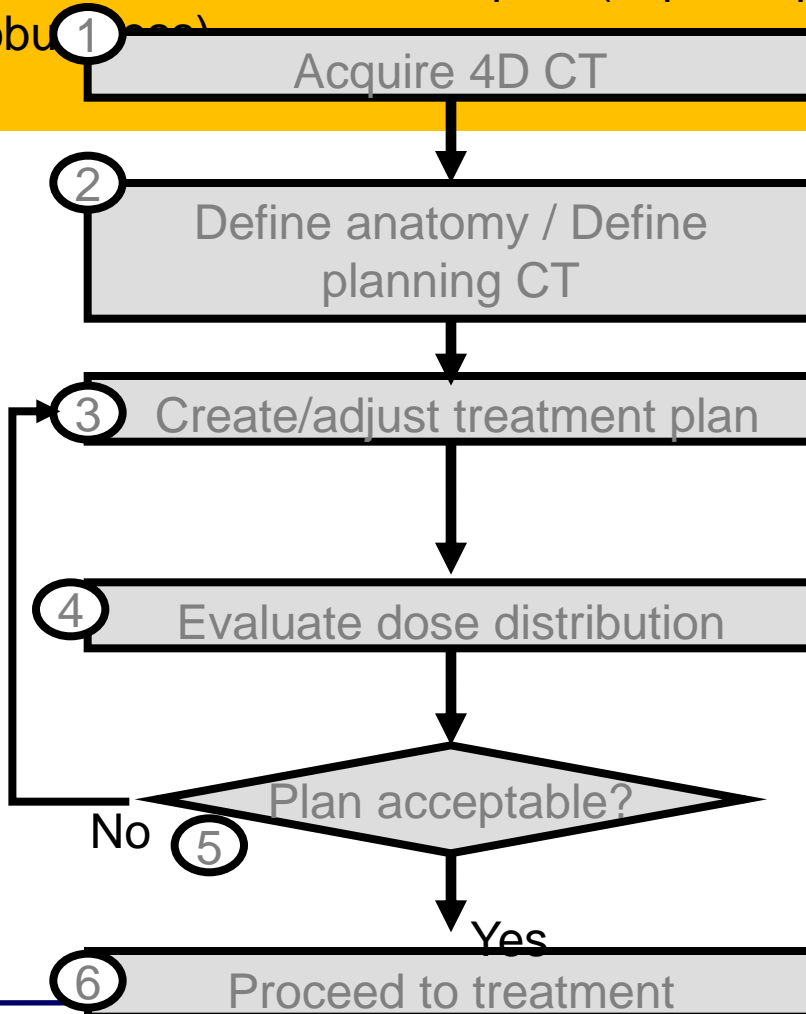
(3) Change/modify the plan such as to reduce/minimize the difference between the calculated and delivered plan (improve plan robustness)



Slide adapted from P Keall

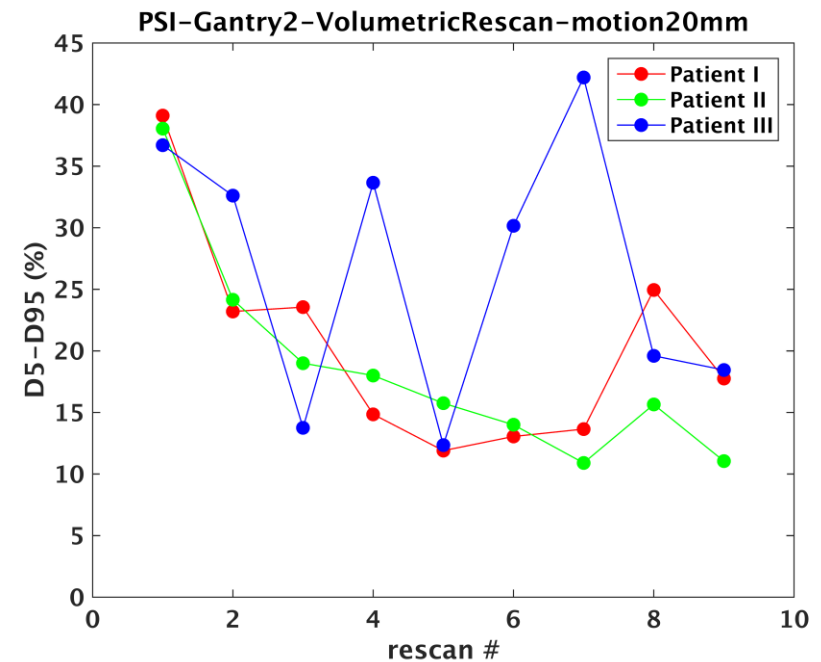
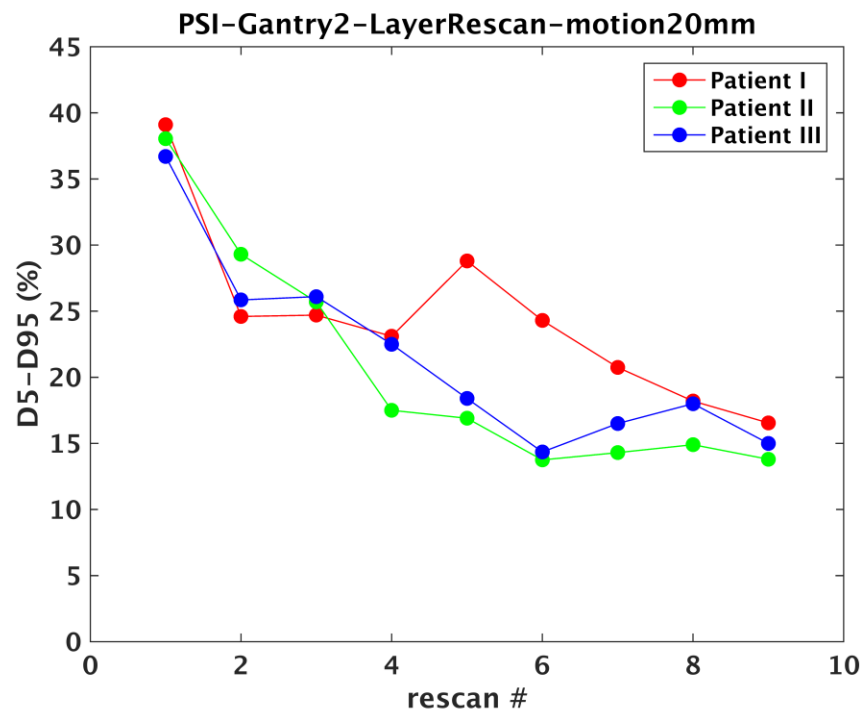
Challenges (3)

(3) Change/modify the plan such as to reduce/minimize the difference between the calculated and delivered plan (improve plan robustness)



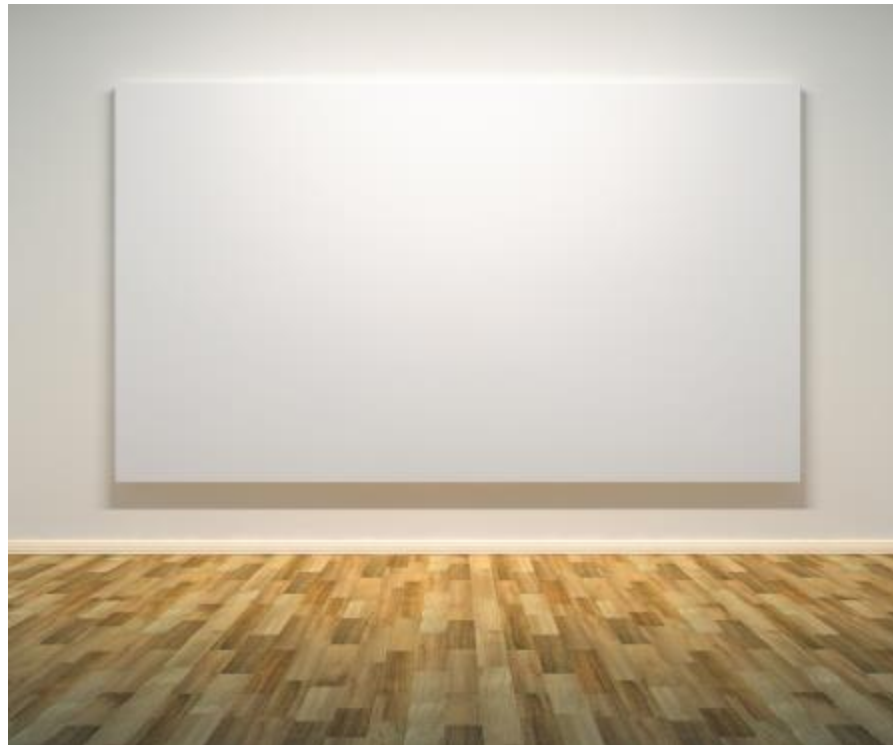
(3) Change/modify the plan such as to reduce/minimize the difference between the calculated and delivered plan (improve plan robustness)

Suggestion on how to improve the plan robustness to motion



Ye Zhang *et al* 2015 *Phys. Med. Biol.*

(3) Change/modify the plan such as to reduce/minimize the difference between the calculated and delivered plan (improve plan robustness)



Practical-Simplicistic view

1. Calculate a plan on the CT that is the best representation of the treatment anatomy (for each treatment day);
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What is commercially available

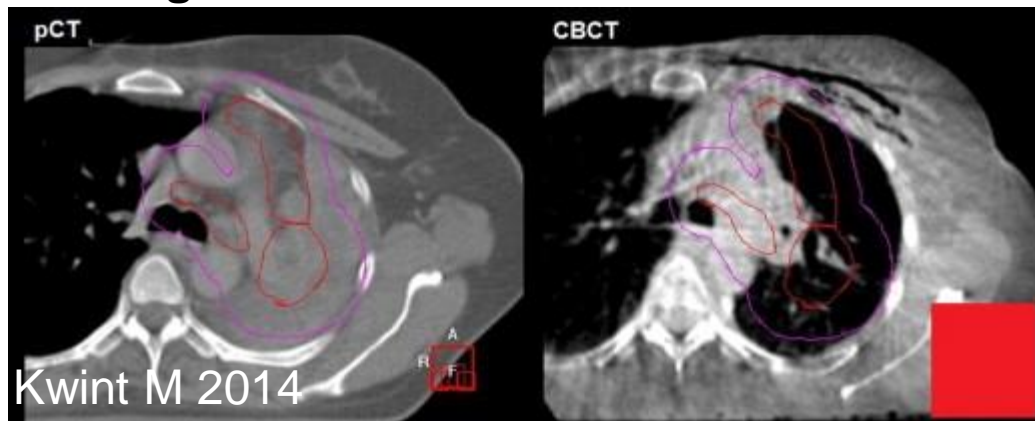




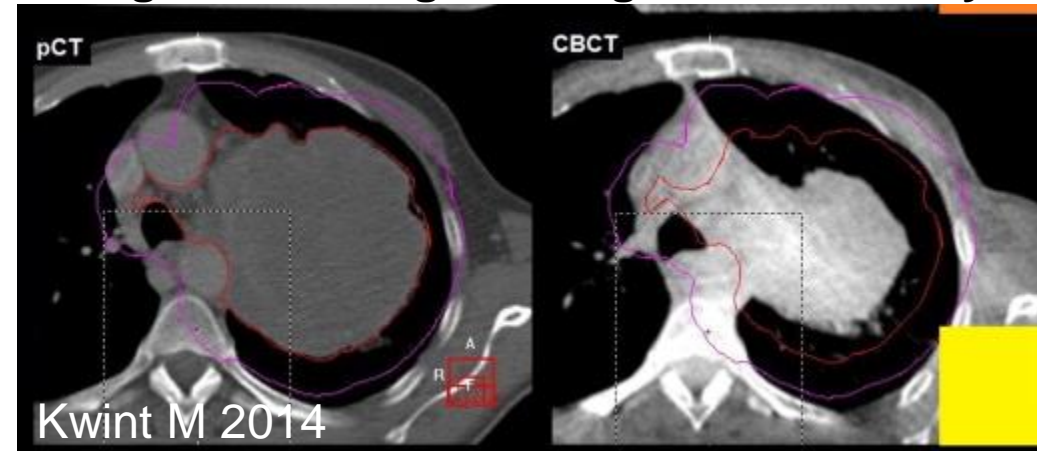
Extra challenges: when treating lung patients

intra thoracic anatomical changes:
occurs > 70% cases during irradiation (Kwint (NKI) Rad Oncol 2014)

Target miss: tumour shift outside PTV



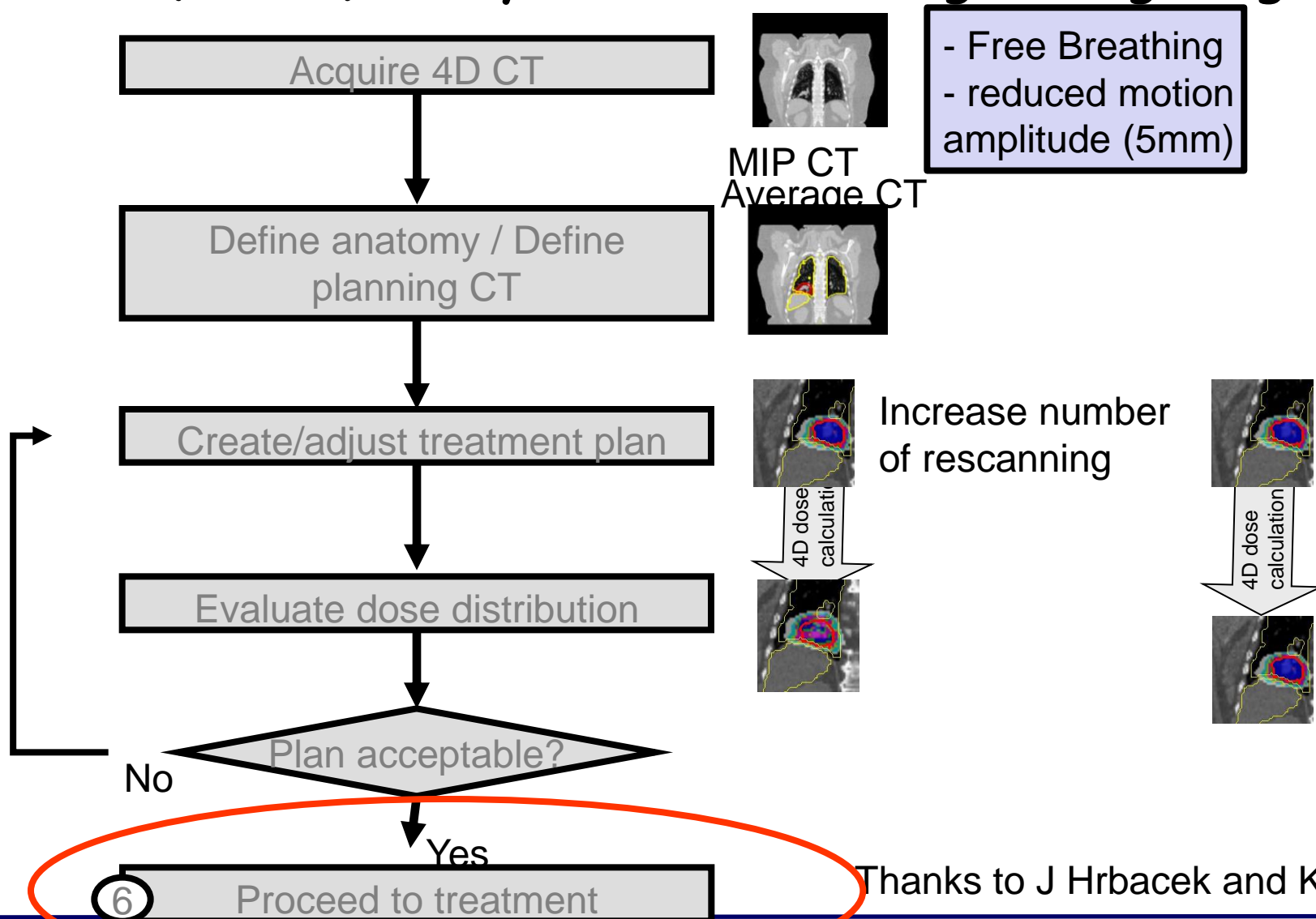
Target shrinkage: change in the density



Necessity to daily adapt the plan
(NOT currently CLINICALLY AVAILABLE)



...we are (almost) ready to start treating moving target !



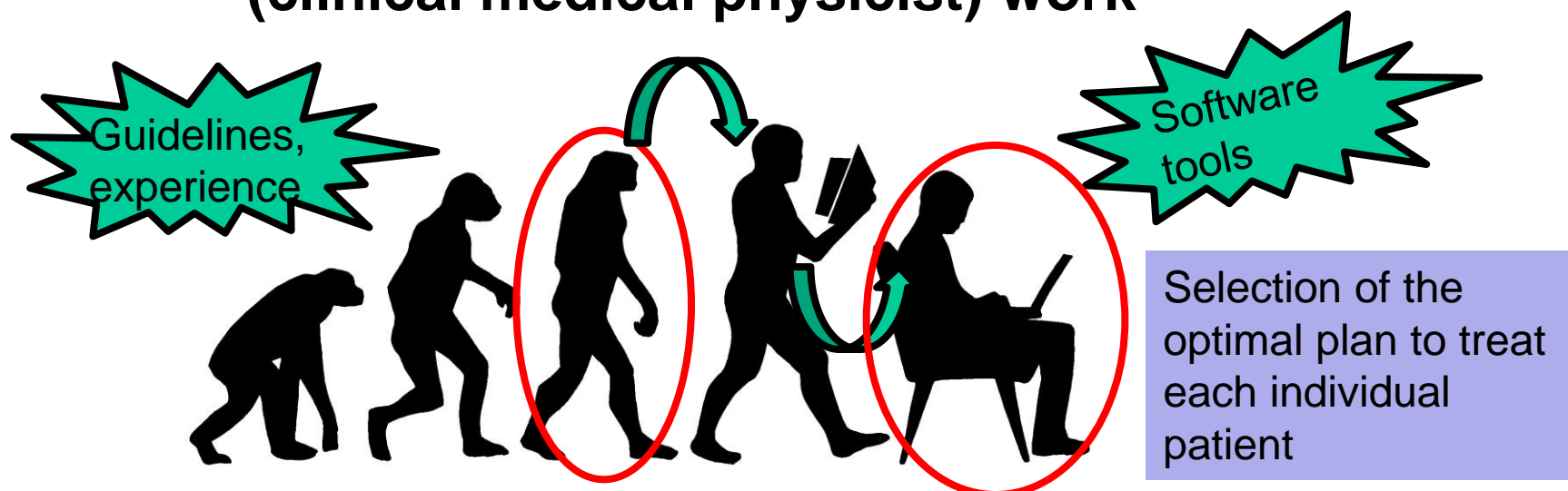
Thanks to J Hrbacek and K Bernatowicz

Summary

Still lack of experience, lack of clear guidelines ...but more and more centers are moving towards these new indications (c.f. Antje)

Vendors are starting to support us (4D data handling, DIR modules,...)

BUT still more tools (4D dose calculation and motion mitigation strategies and planning suggestions) are required to support our (clinical medical physicist) work



Thank you

Thanks to



PSI:
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