Image guided Radiotherapy: Surrogates for toxicity?

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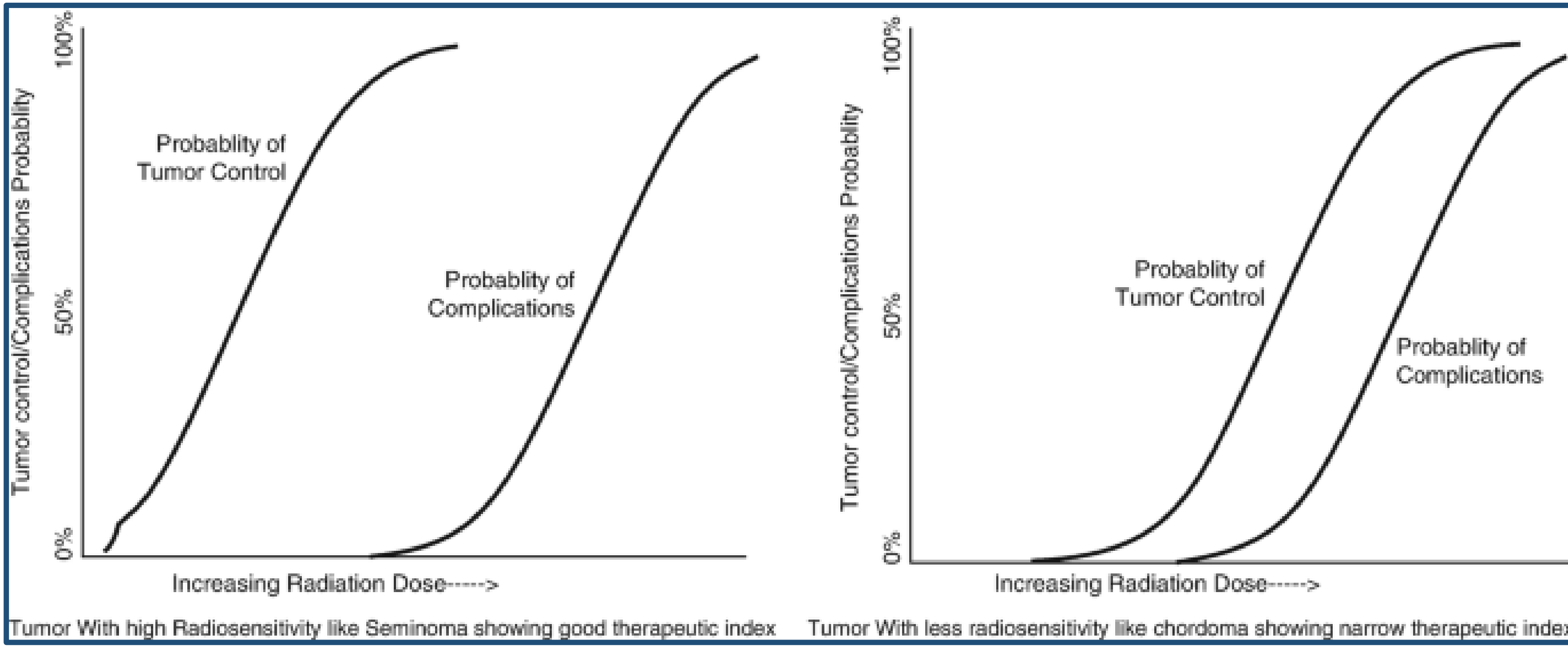


Therapeutic ratio

Goal : elimination of tumour with nil to minimum damage to surrounding healthy tissues

This delicate balance between the radiation dose–response relationship for tumor cell kill and probability of normal tissue toxicity represents the core principle and also the main challenge of radiation oncology

What is IGRT?

- Medical imaging for tumor localization during the preparation phase, as well as in the treatment room for localization of the tumor and directing the beam

  i) therapy guidance (target and OaRs definition)

  ii) treatment plan verification (inter-fraction management)

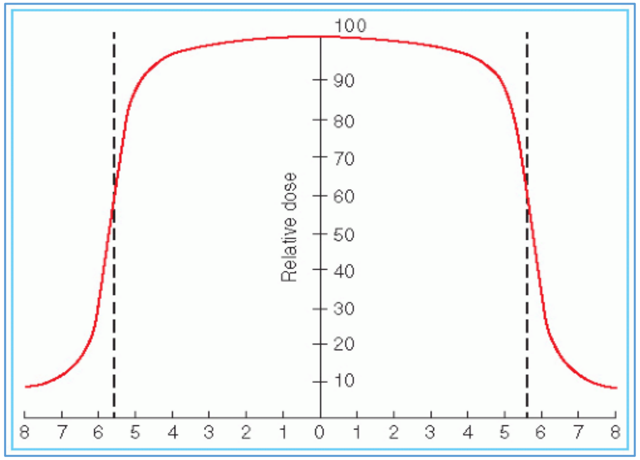
  iii) real-time delivery control (intra-fraction management).

- Theoretical definition to practical definition

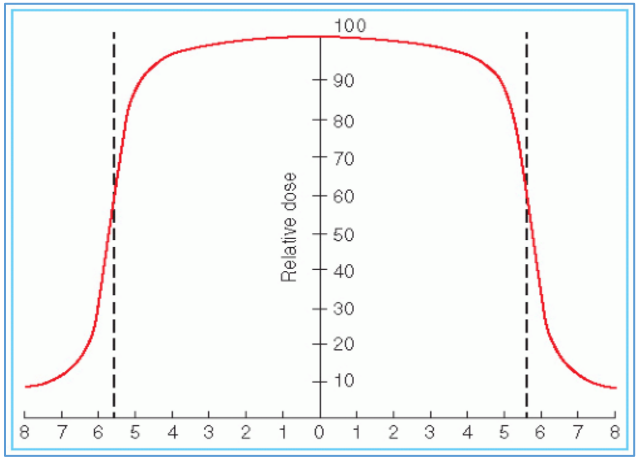
Why is IGRT needed in the era of modulated treatments?

- Margin reduction
- Impacts toxicity
- To avoid geographical miss
- Facilitates adaptive radiotherapy

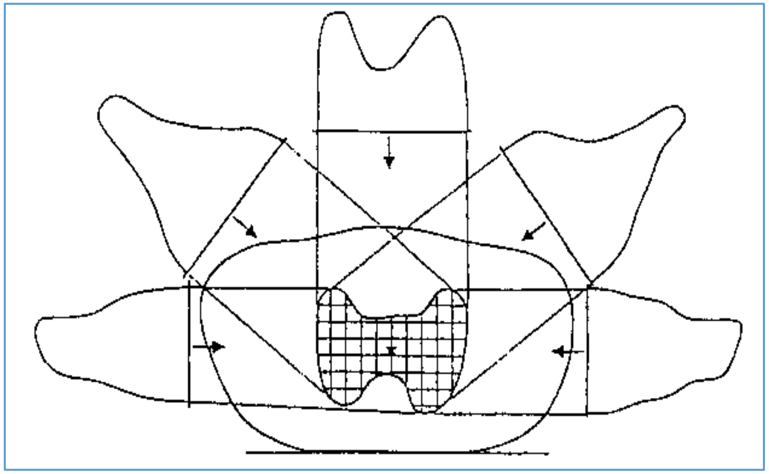
2DRT



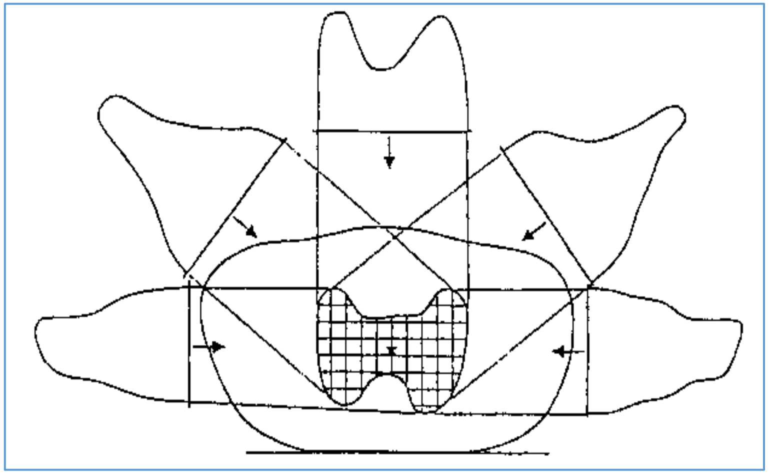
3DCRT



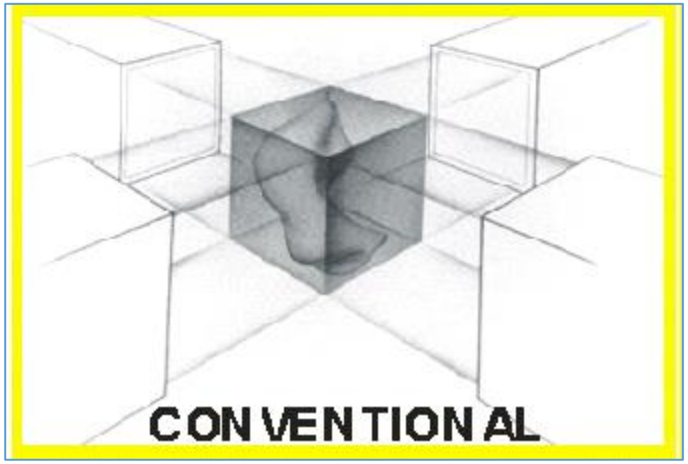
IMRT



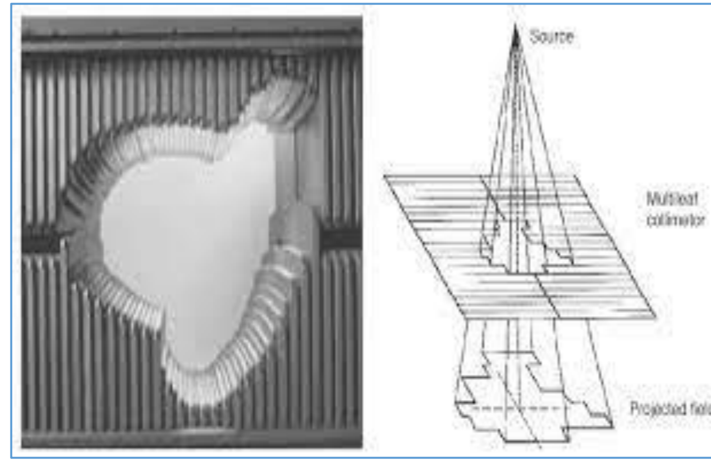
VMAT



2DRT

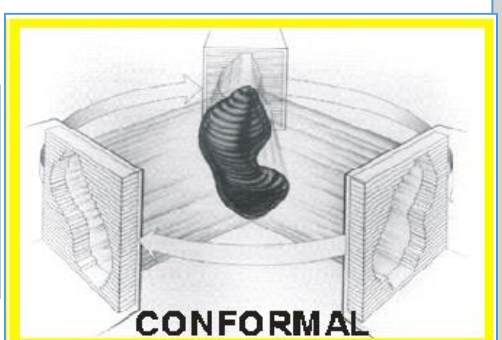


3DCRT

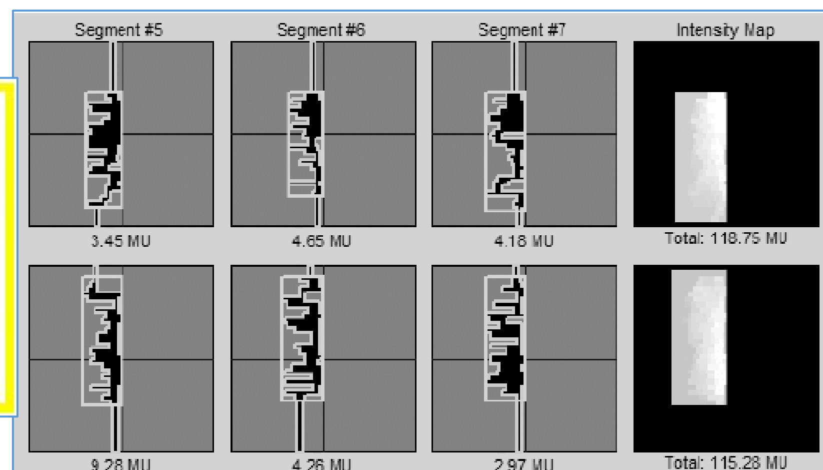


IMRT

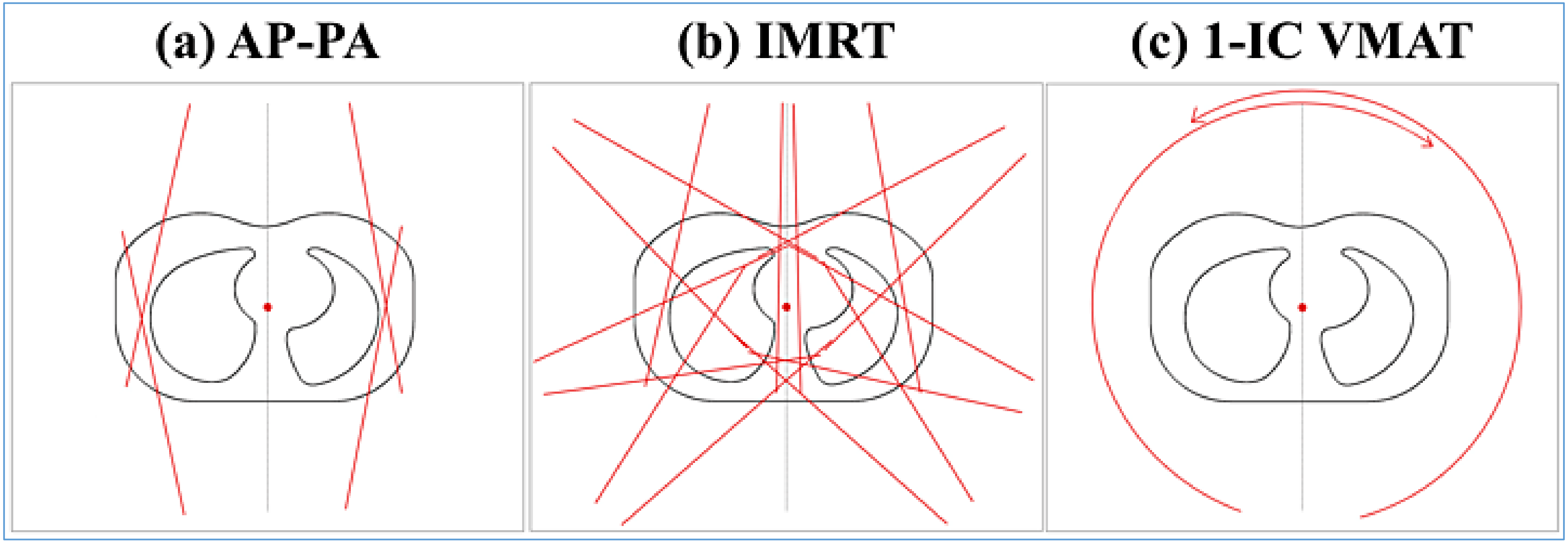
At multiple fixed gantry angles

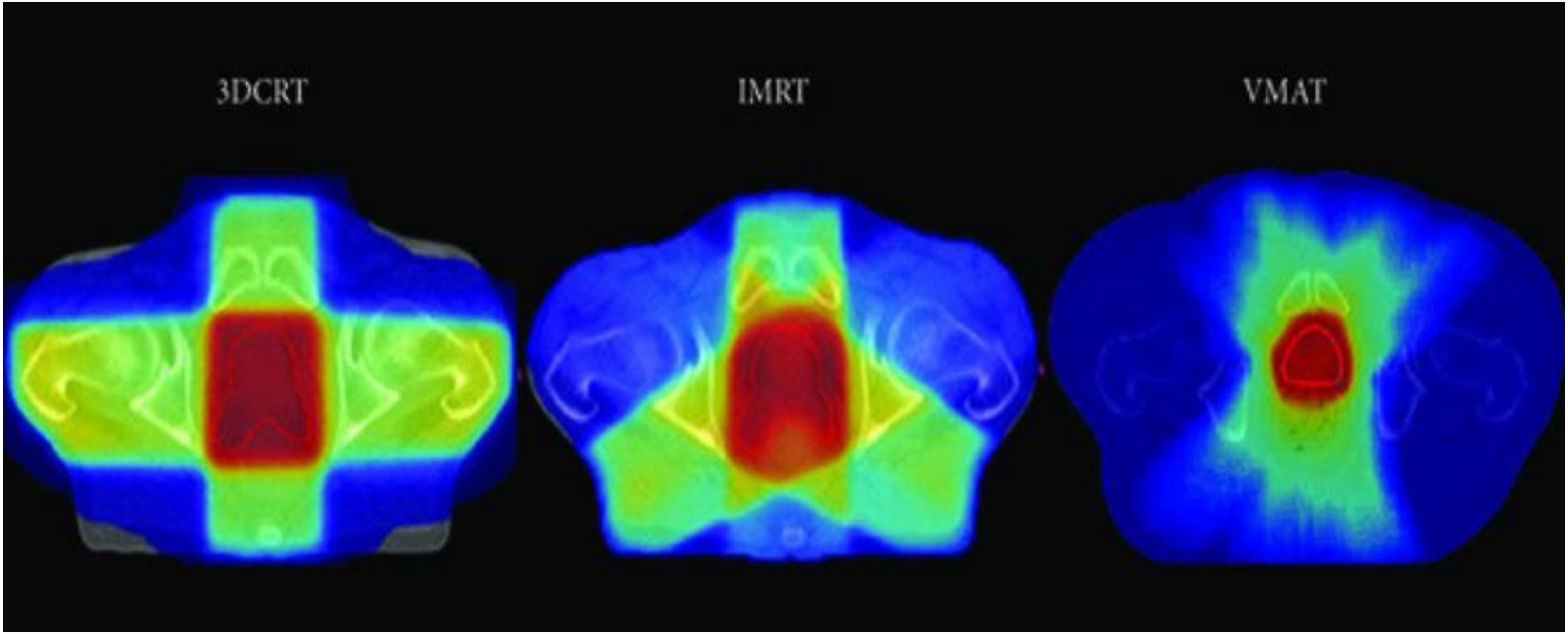


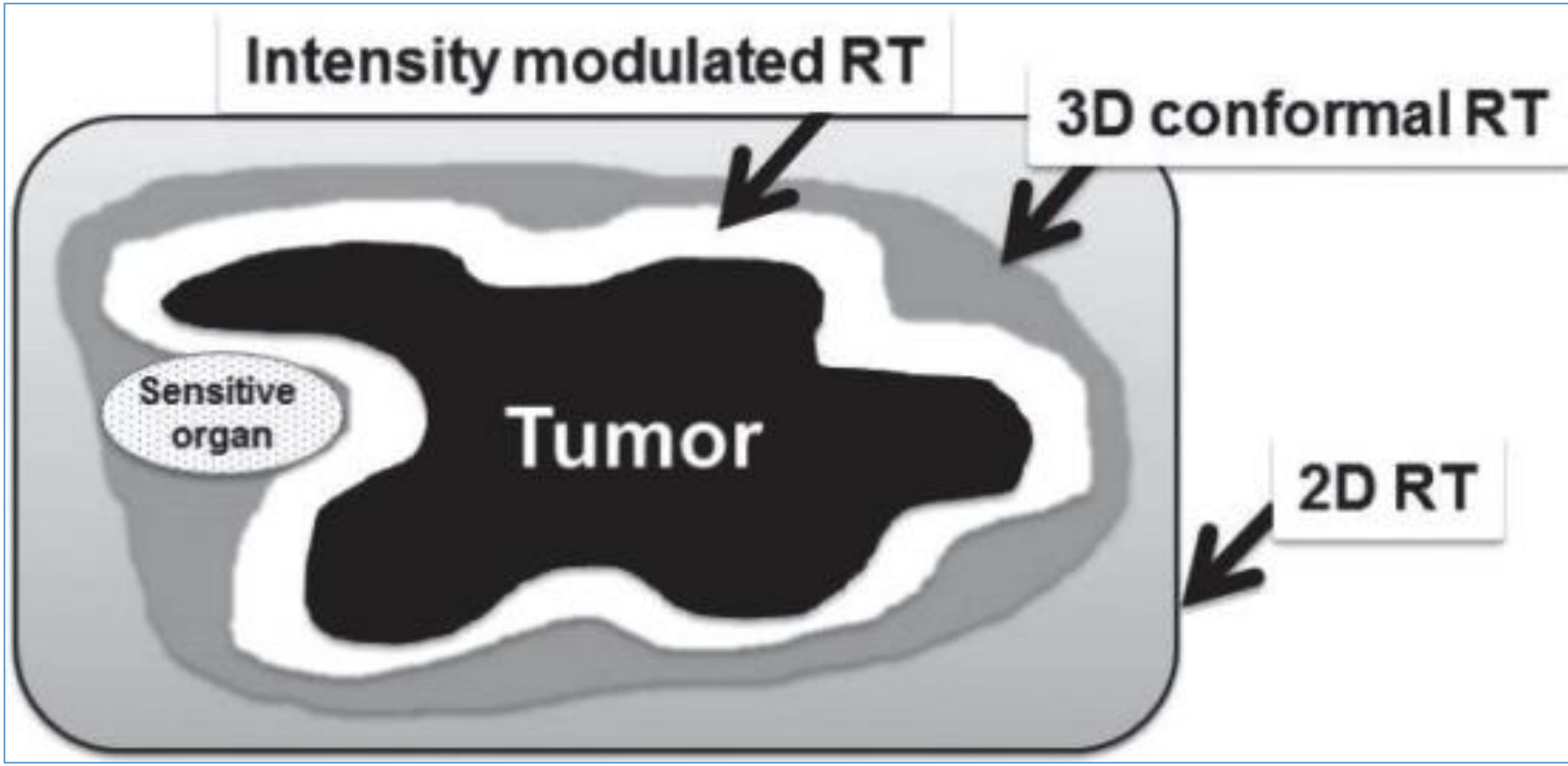
VMAT



Across the full arc


(a) AP-PA
(b) IMRT
(c) 1-IC VMAT


3DCRT
IMRT
VMAT

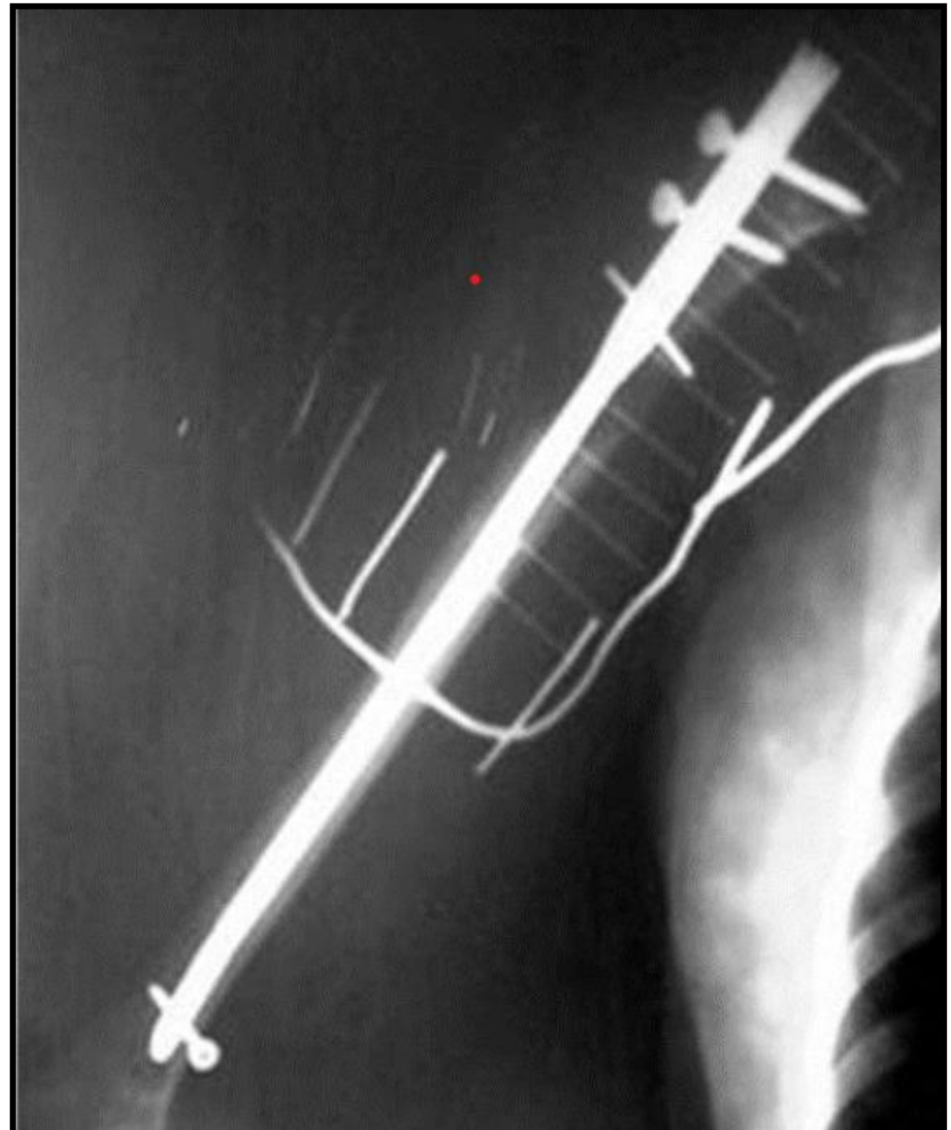


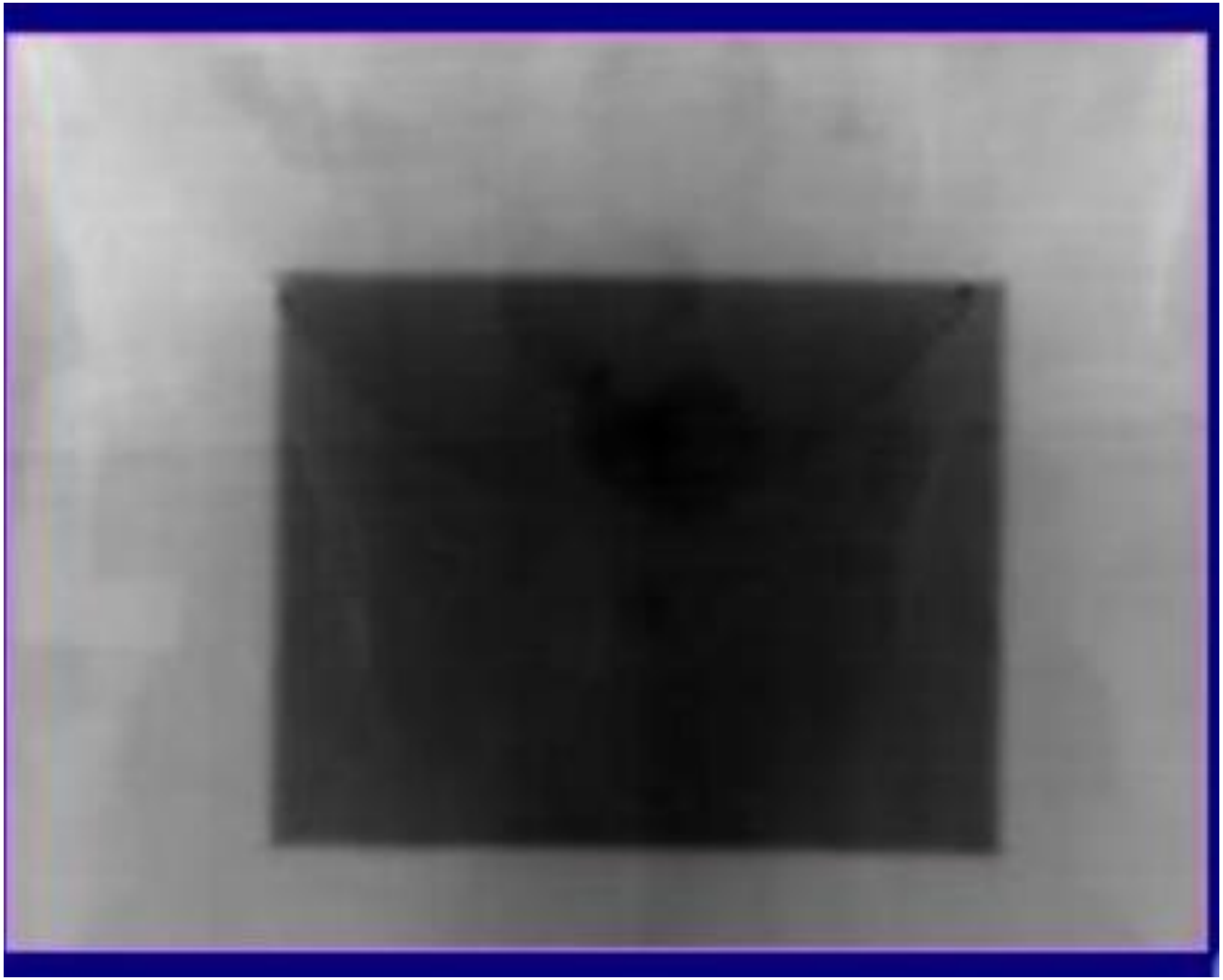
Intensity modulated RT
3D conformal RT
2D RT
Sensitive organ
Tumor

Why is IGRT needed in the era of modulated treatments?

- Margin reduction
- Impacts toxicity
- To avoid geographical miss
- Facilitates adaptive radiotherapy

How did we do IGRT few years back?

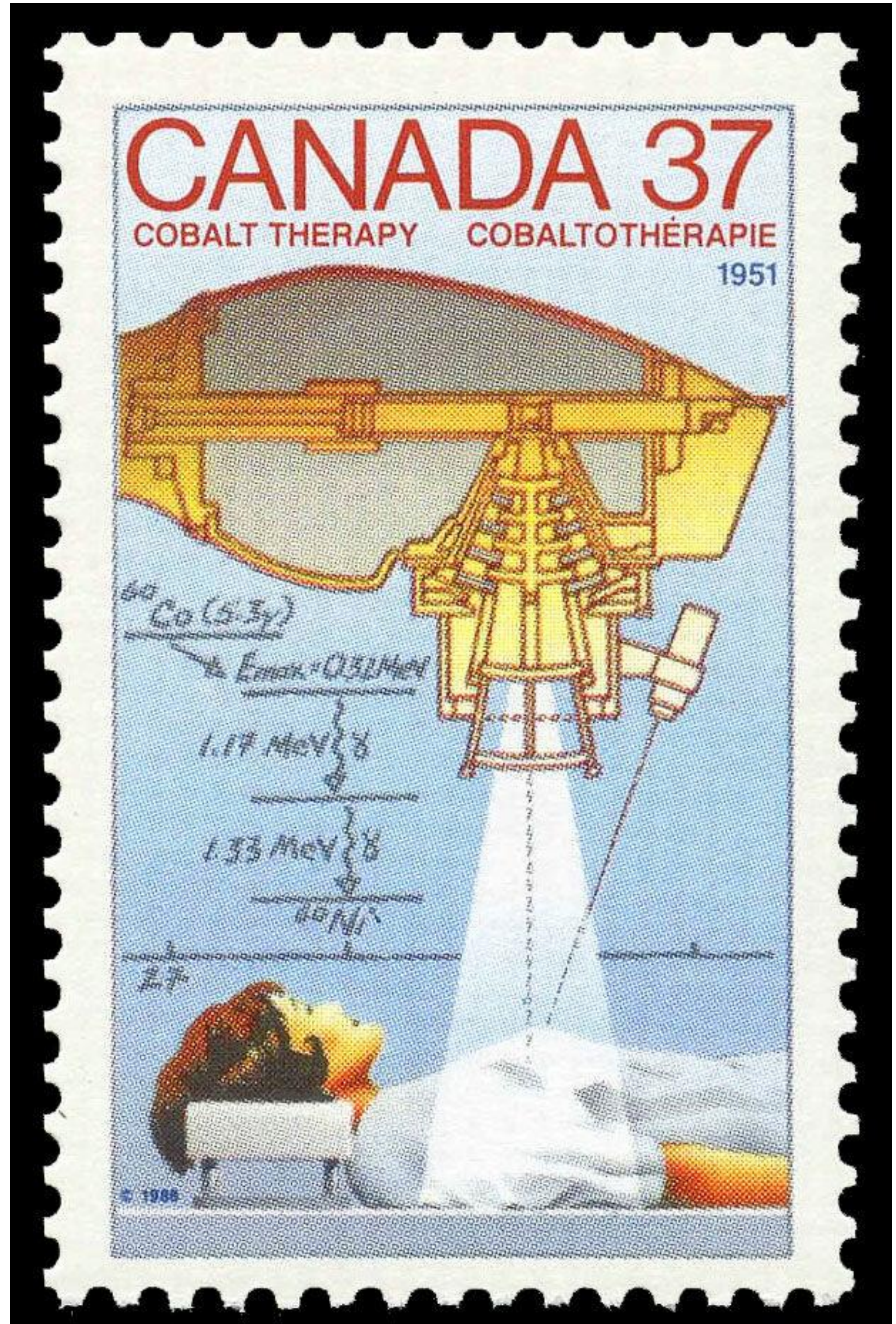




PORT FILM


ATC

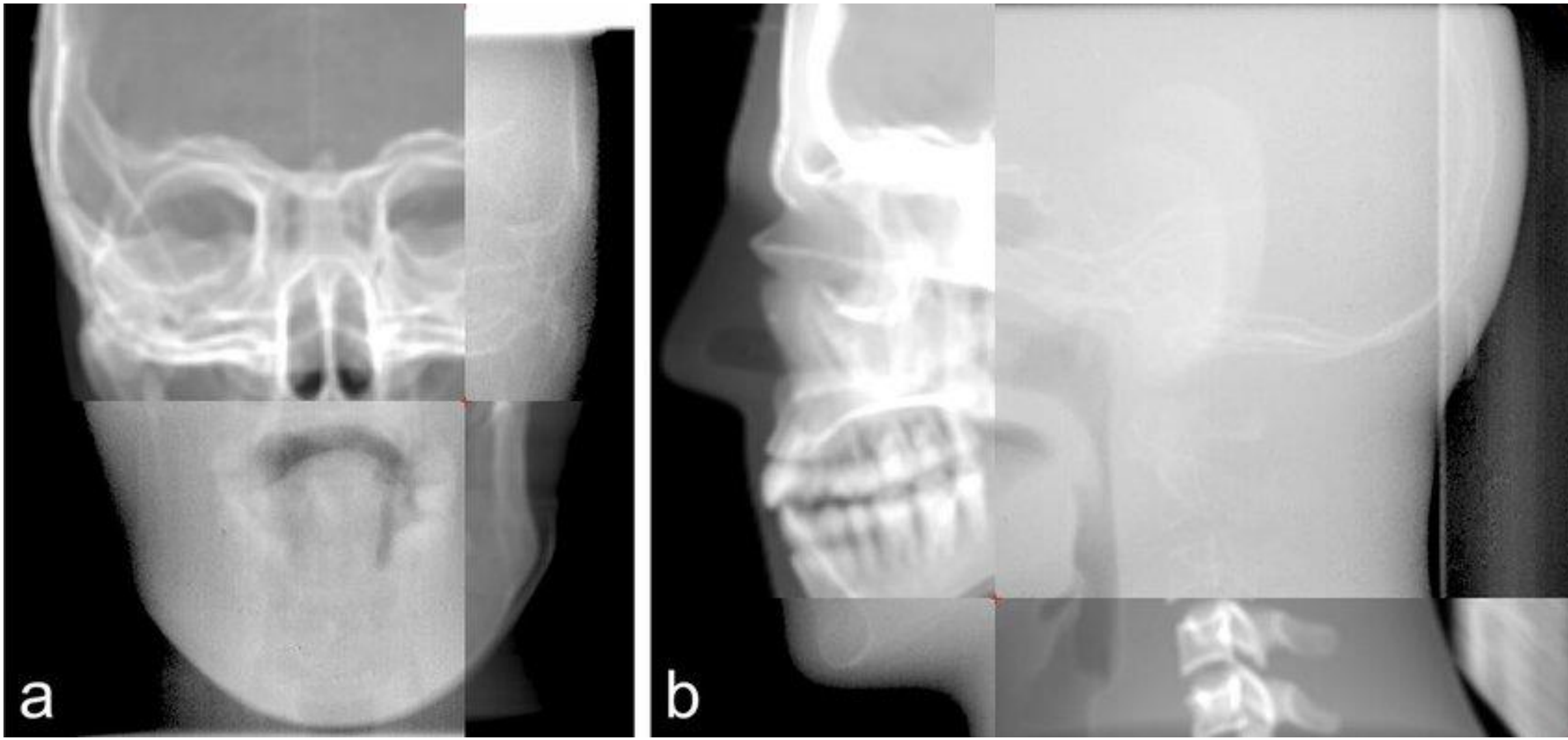
- Usually taken before or after treatment
- If the field itself doesn't show enough anatomy, a double exposure technique can be used



EPID: Electronic Portal Imaging Device

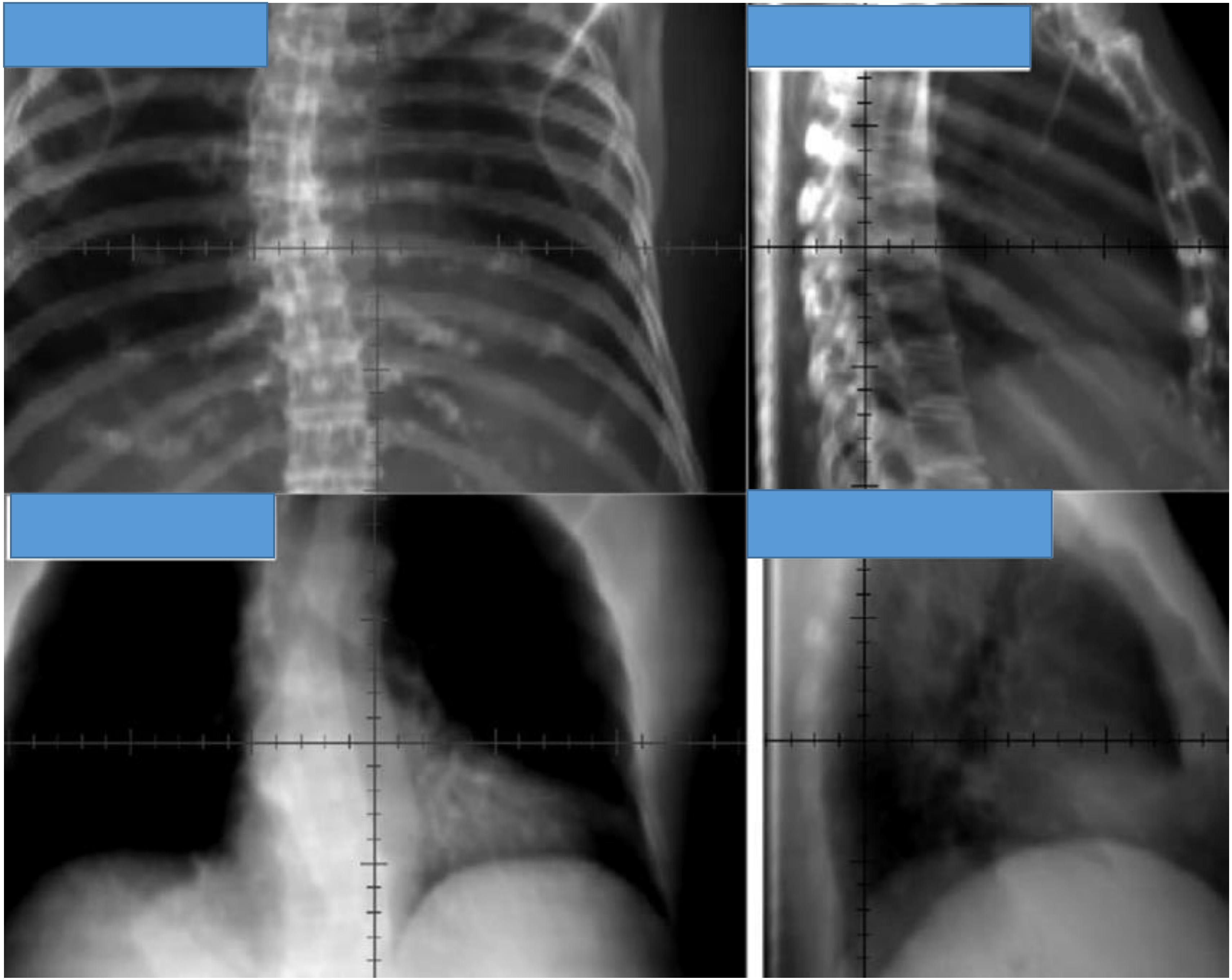
For EPID, instead of a film, an **electronic portal imaging device** is placed in the exit beam to produce the image. The images are captured and displayed on a video screen.

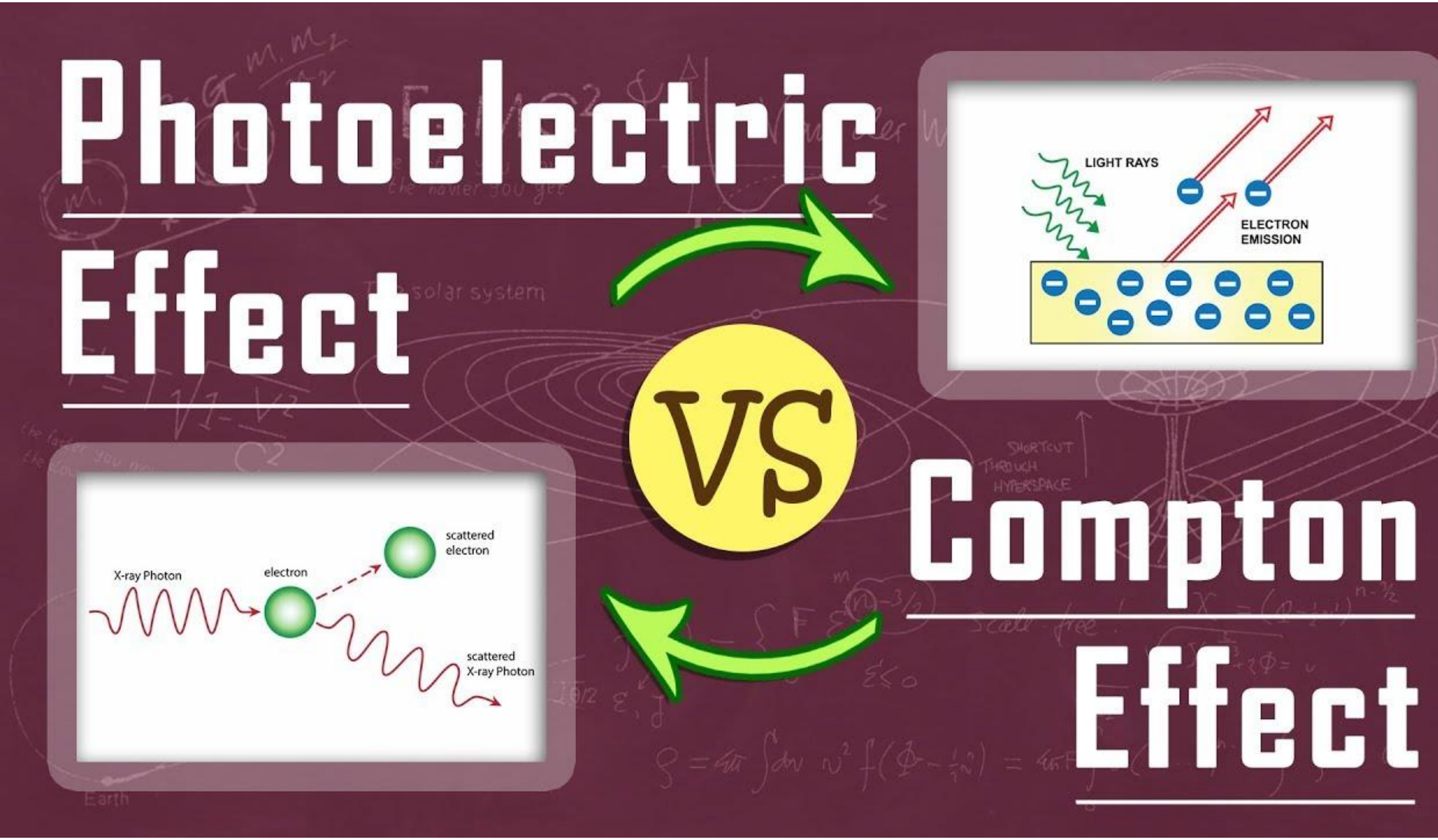
- Digital
- Instantaneous
- Can be processed to enhance various attributes.
- Can be compared with the simulation films to determine the placement differences.
- Can be monitored throughout the treatment, and motion during the therapy can be detected.

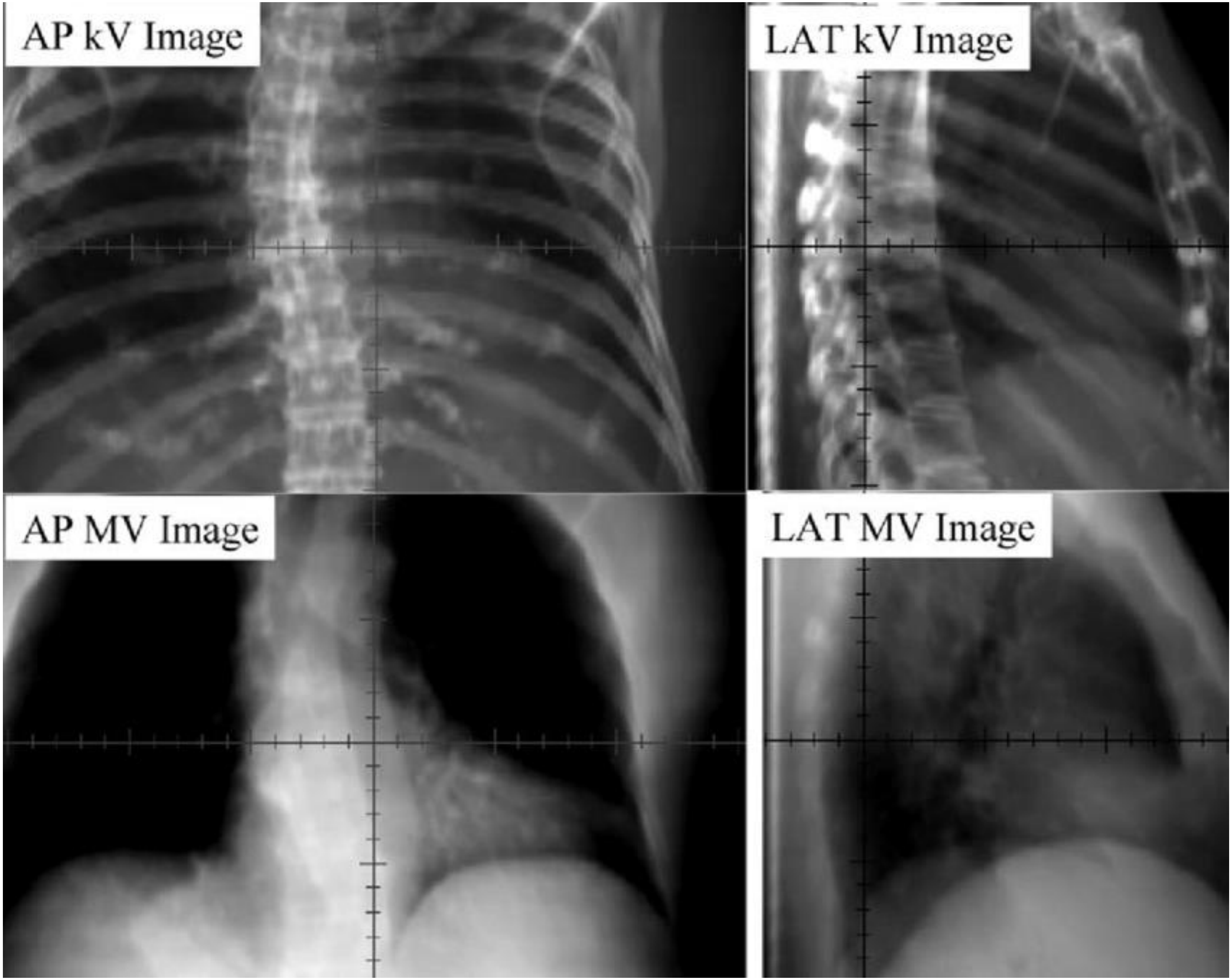

a
b

- MV EPID- MV beam with its own flat panel detector
- KV EPID- with a separate mounted x ray tube and its detector

Which is better ? And why?




Photoelectric
Effect
LIGHT RAYS
ELECTRON
EMISSION
VS
Compton
Effect
X-ray Photon
electron
scattered
electron
scattered
X-ray Photon


AP kV Image
LAT kV Image
AP MV Image
LAT MV Image

Soft tissue anatomy not appreciated in either and the tumour and OARs are not visible in either…

hence need for 3D imaging!!!

However, it is not useless,

-- helpful in cases of implanted fiducials

-- can be used in fluoroscope mode

-- MV portal verification van be used for online monitoring of beam and target position

Volumetric imaging

Treatment can be adapted to compensate for changes in the absolute and relative position of target and OAR.

Separate CT scanner in the room

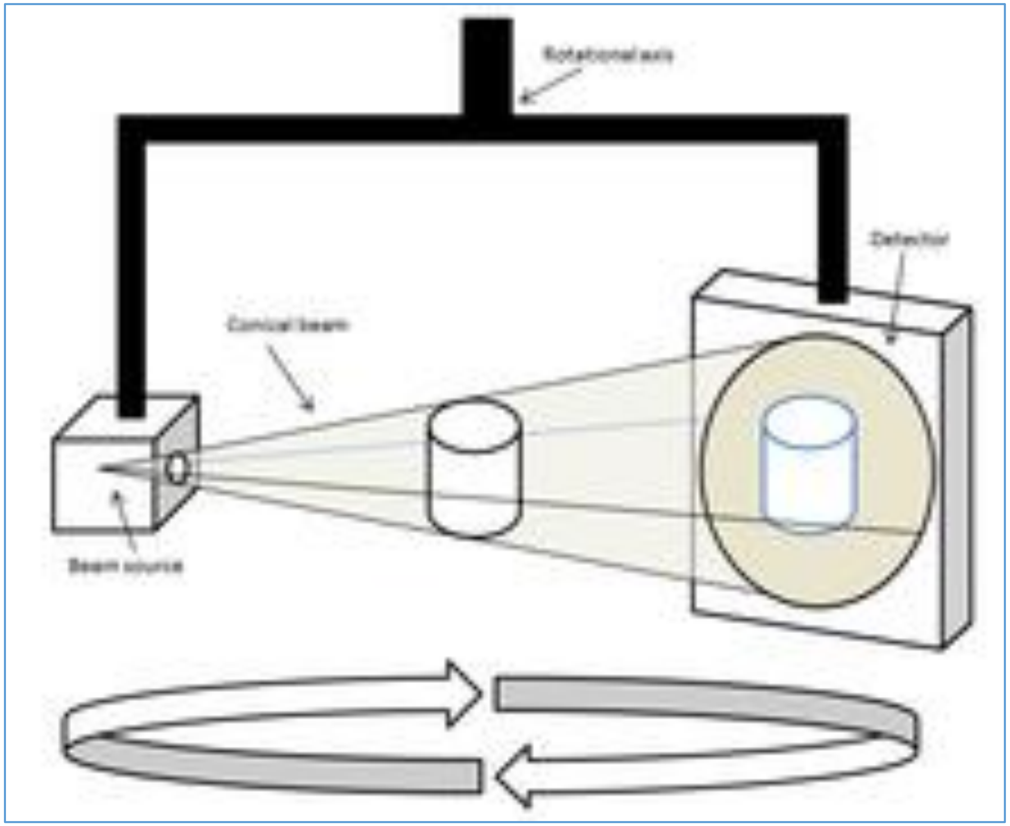
On rails or robotic movement of couch

CT on rails – the couch shared between the scanner and the accelerator

- Transitioned from crude versions
- Gives diagnostic quality images but has its own ifs and buts..

CBCT: Cone Beam CT

- Integration of CBCT on an accelerator (gantry-based CBCT) was first proposed around 1997; the first prototypes were constructed in Beaumont and Toronto prior to the year 2000 in collabora- -tion with Elekta.



- Main advantage of CBCT-

  Shares the isocentre with the treatment machine and hence no movement required between imaging and treatment

- Disadvantages-
  Slow, quality inferior to fan beam and interface blurring

CBCT


Transversale - CT_1 - CBCT_1 - 04 janv. 2017 10:08
Isocentre de traitement non disponible : Aucun champ de traitement.
Sagittale - CT_1 - CBCT_1 - 04 janv. 2017 10:08
Frontale - CT_1 - CBCT_1 - 04 janv. 2017 10:08

4D- CBCT

CBCT imaging facilitates visualization of tumors that move under respiratory motion without motion blurring (requirement for accurate image guidance of mobile tumors moving over 1 cm).

Breath hold CBCT

Binning is possible, generating Maximum Intensity projections; Quality ??

iCBCT: iterative CBCT, etc

With iCBCT, advanced algorithms reduce noise and artifacts, yielding higher quality images than was possible with earlier standard approaches to CBCT.

Advanced algorithms reduce noise and artifacts, yielding higher quality images than was possible with earlier standard approaches to CBCT.

HYPERSIGHT- faster and with more resolution!

Extended CBCT

- Medulloblastomas
- Neck imaging
- Pelvic + para-aortic

Online CBCT

- ??

- KV images in cine mode

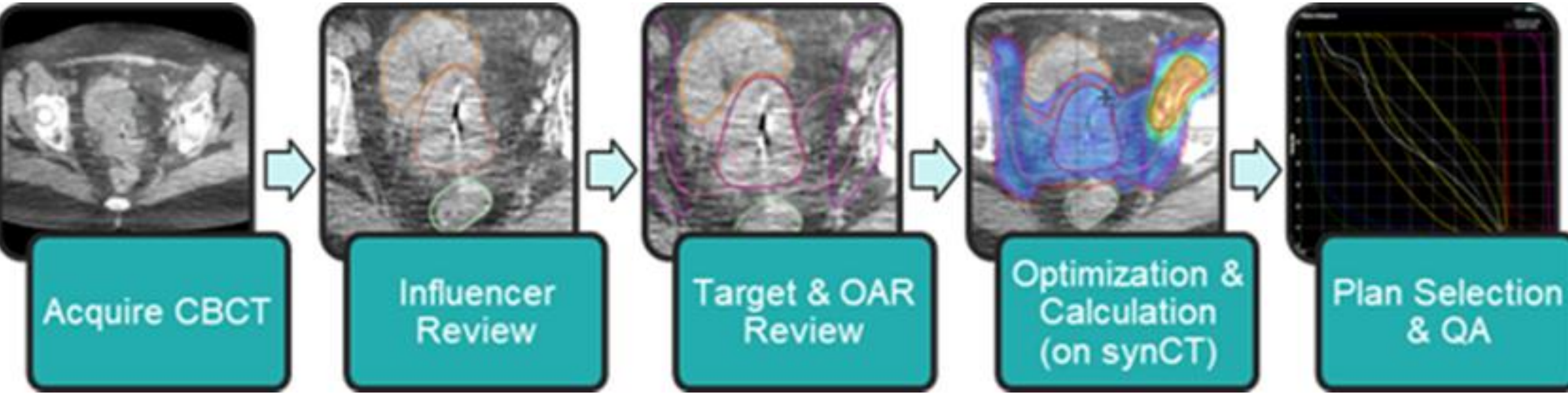
Still existing problems ?

- Significant changes in anatomy, tumour regression cannot be accounted for by mere shifts → needs periodic replanning

- Intra- fraction variations

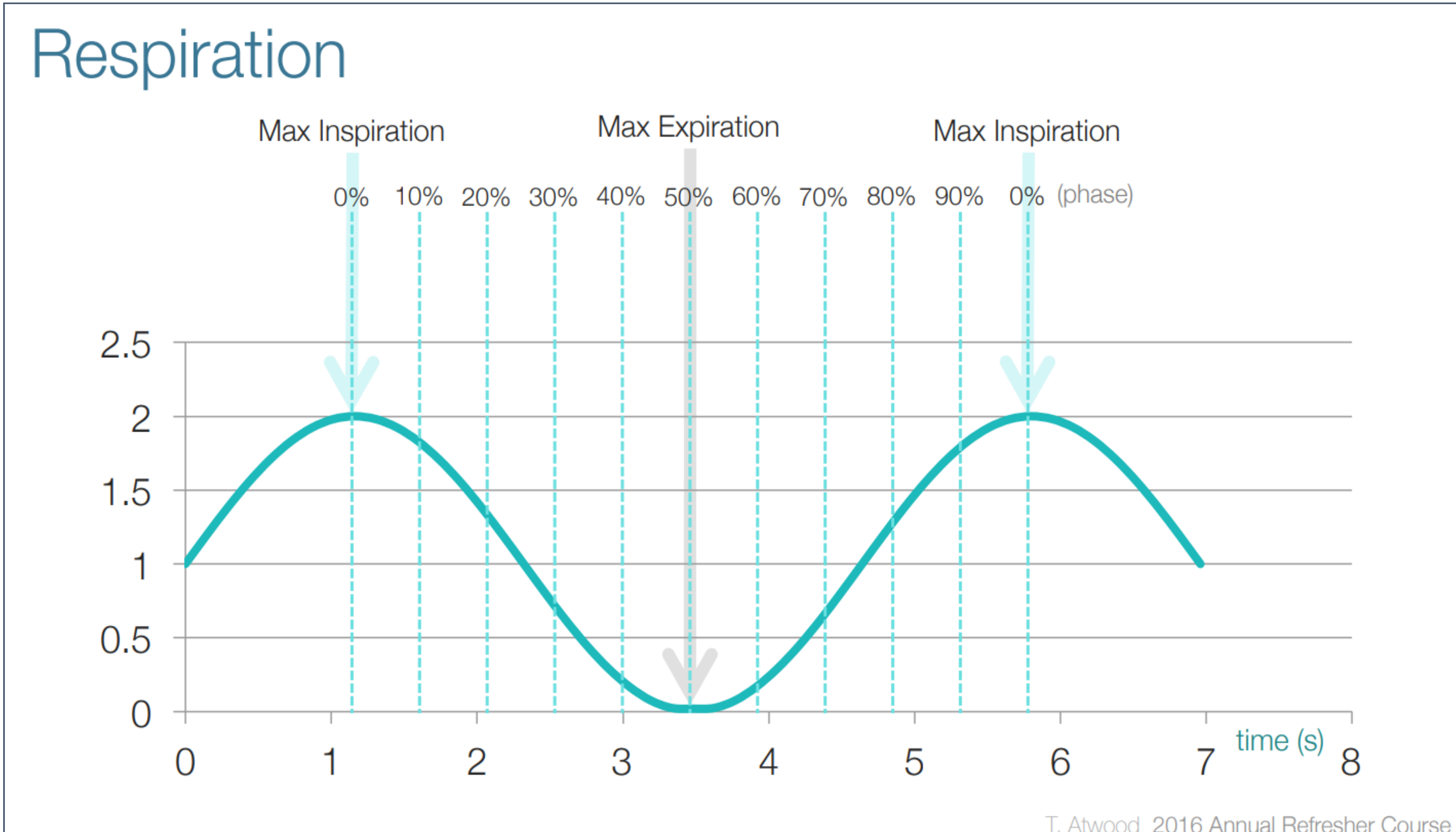
- CT gives volumetric information but is the best in soft tissue contrast? Does it give functional data?

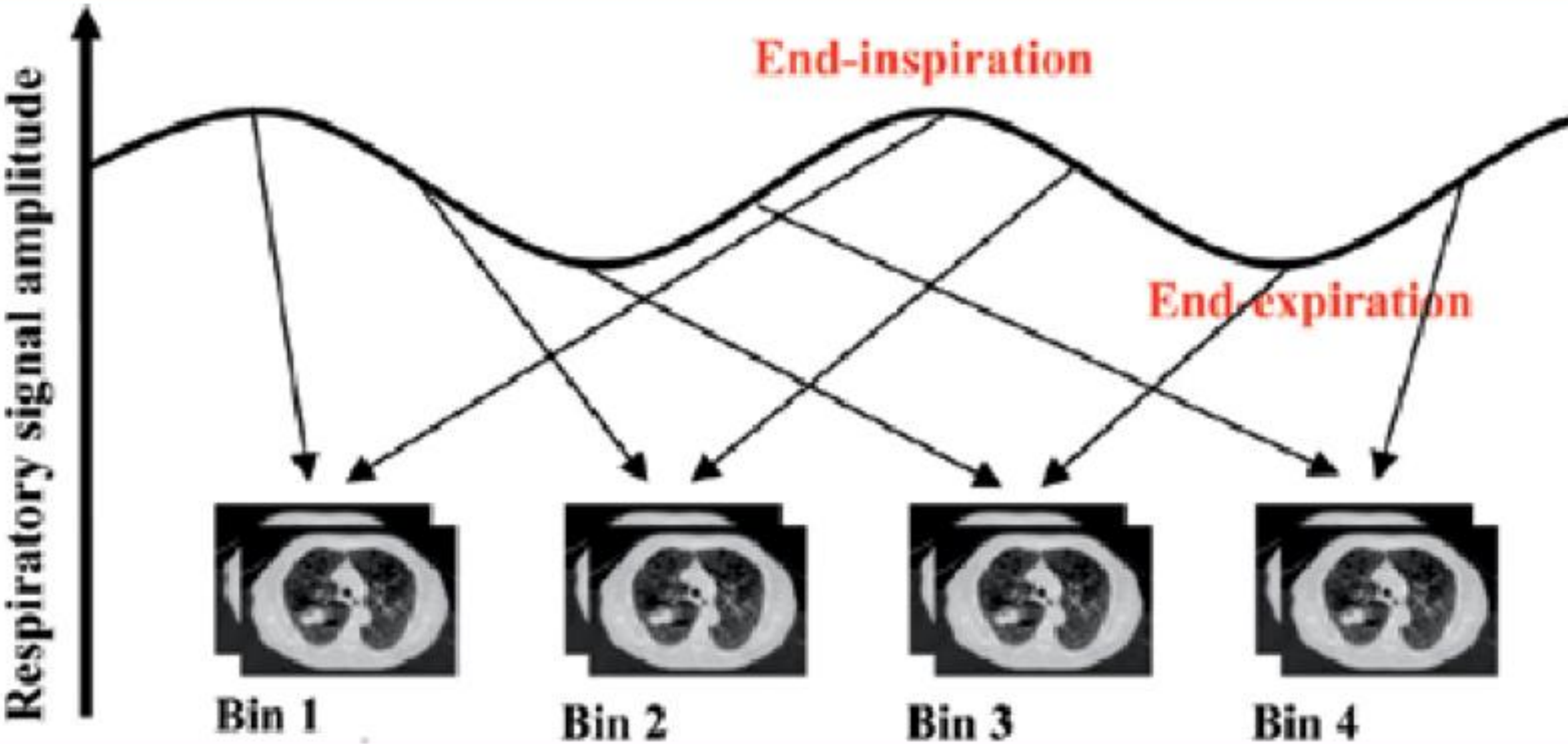
Adaptive RT



Ethos, Varian
Radixact, Accuray
Reflexion (with PETCT)

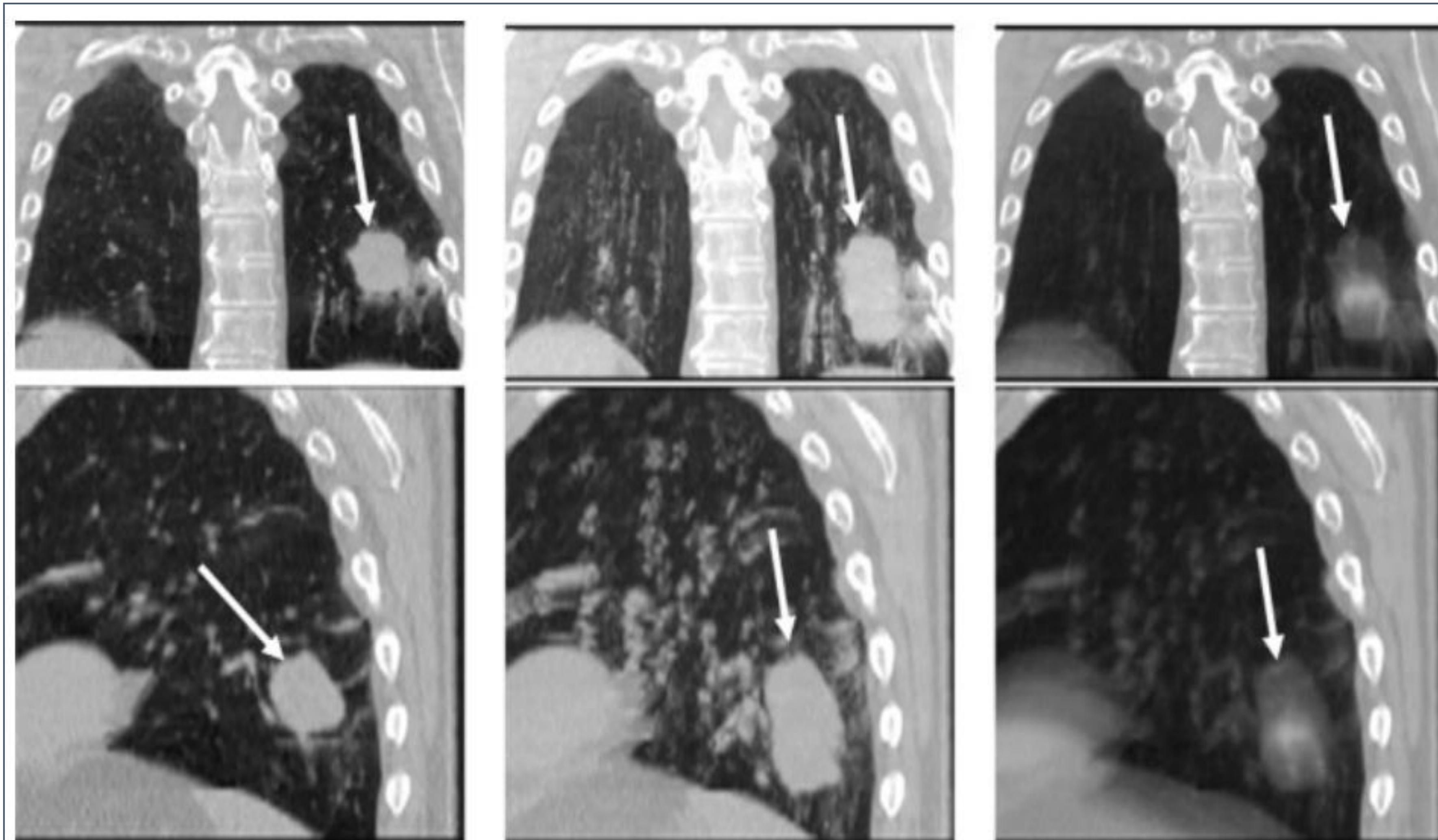
Intra- fraction movements
4D CT sim. & treatment



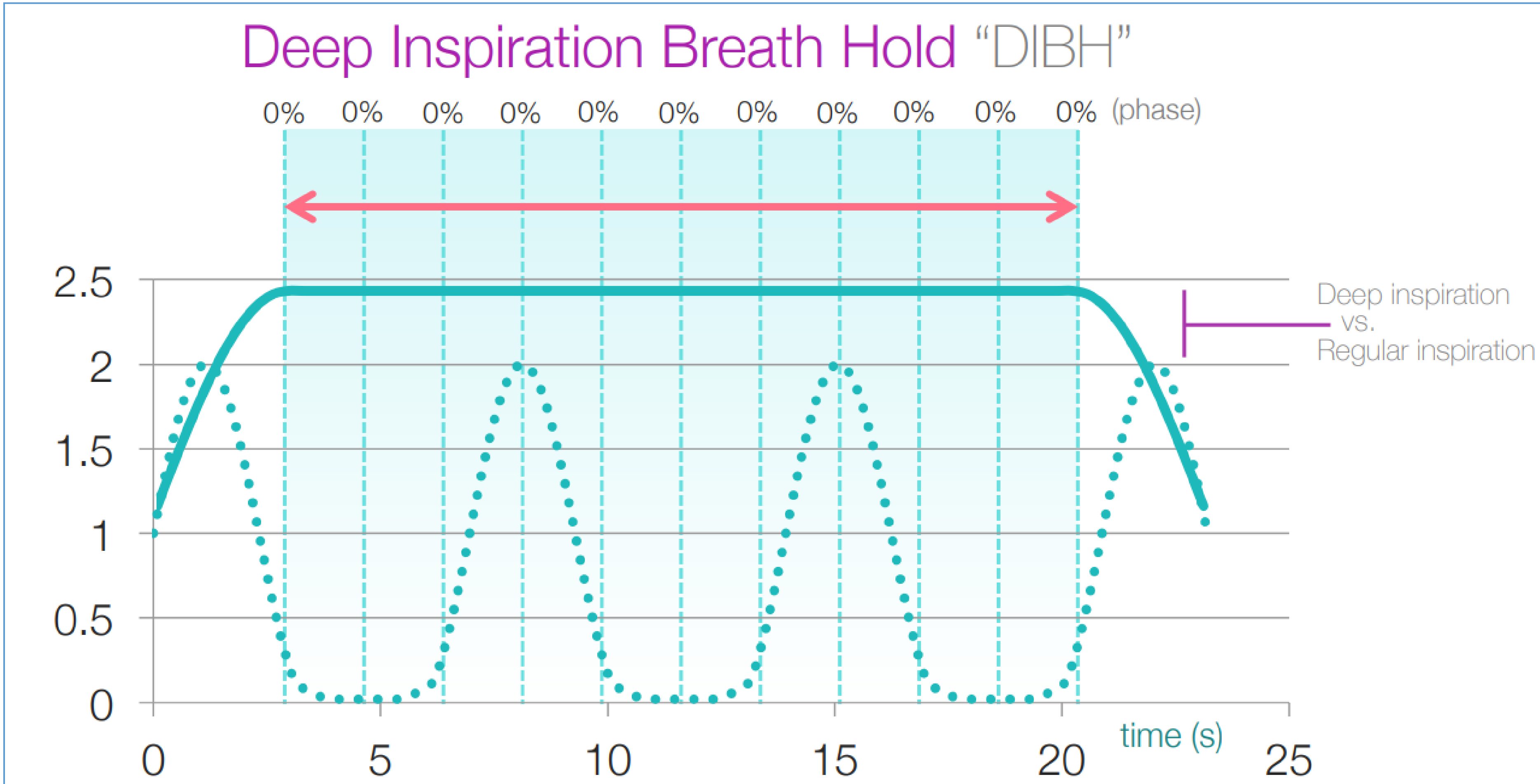


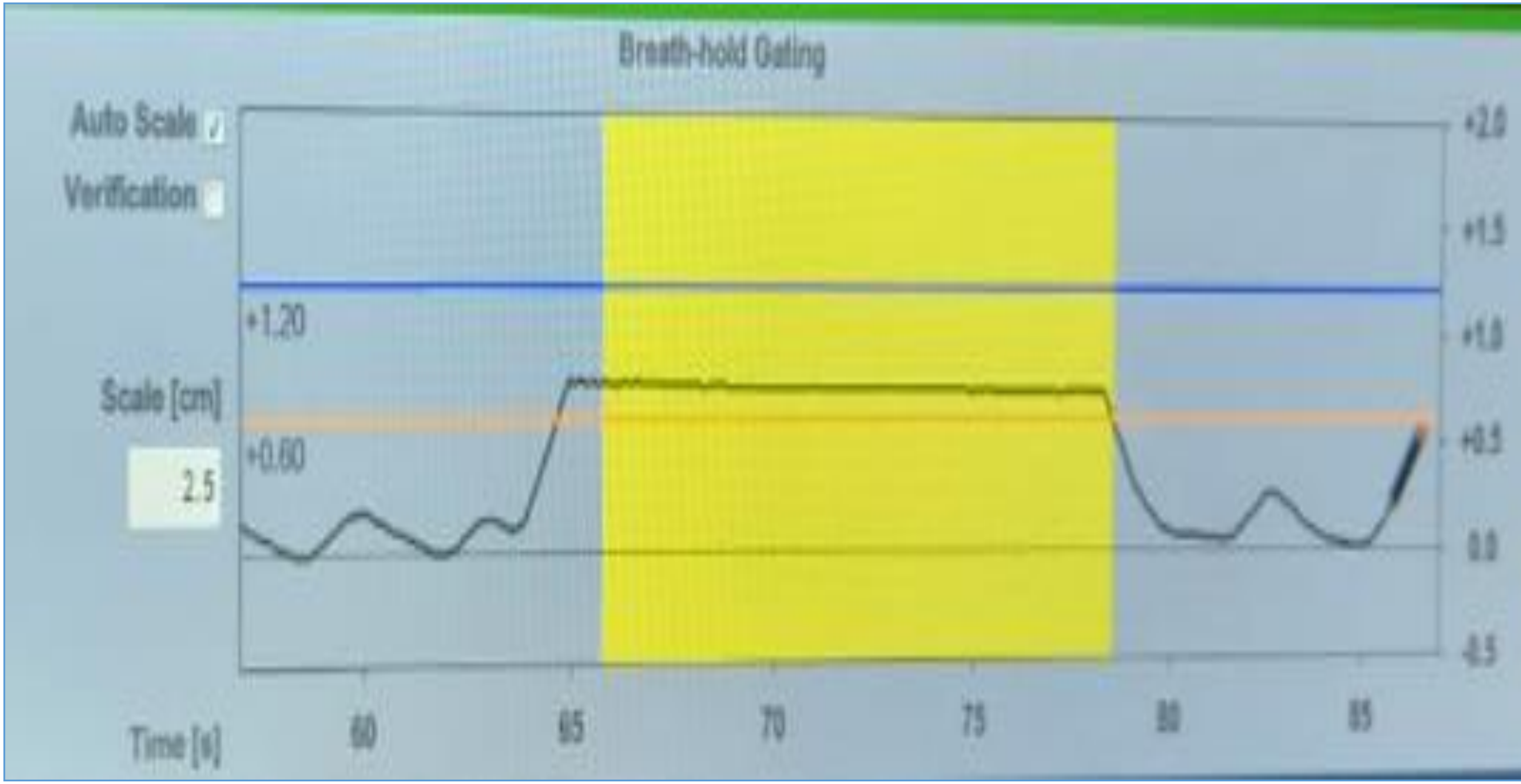
Respiratory signal amplitude
End-inspiration
End-expiration
Bin 1
Bin 2
Bin 3
Bin 4

Phase 50 **MIP** **AvgIP**



Deep Inspiratory Breath Hold





Breath-hold Gating
Auto Scale
Verification
Scale [cm]
2.5
+1.20
+0.60
+2.0
+1.5
+1.0
+0.5
0.0
-0.5
Time [s]
60
65
70
75
80
85

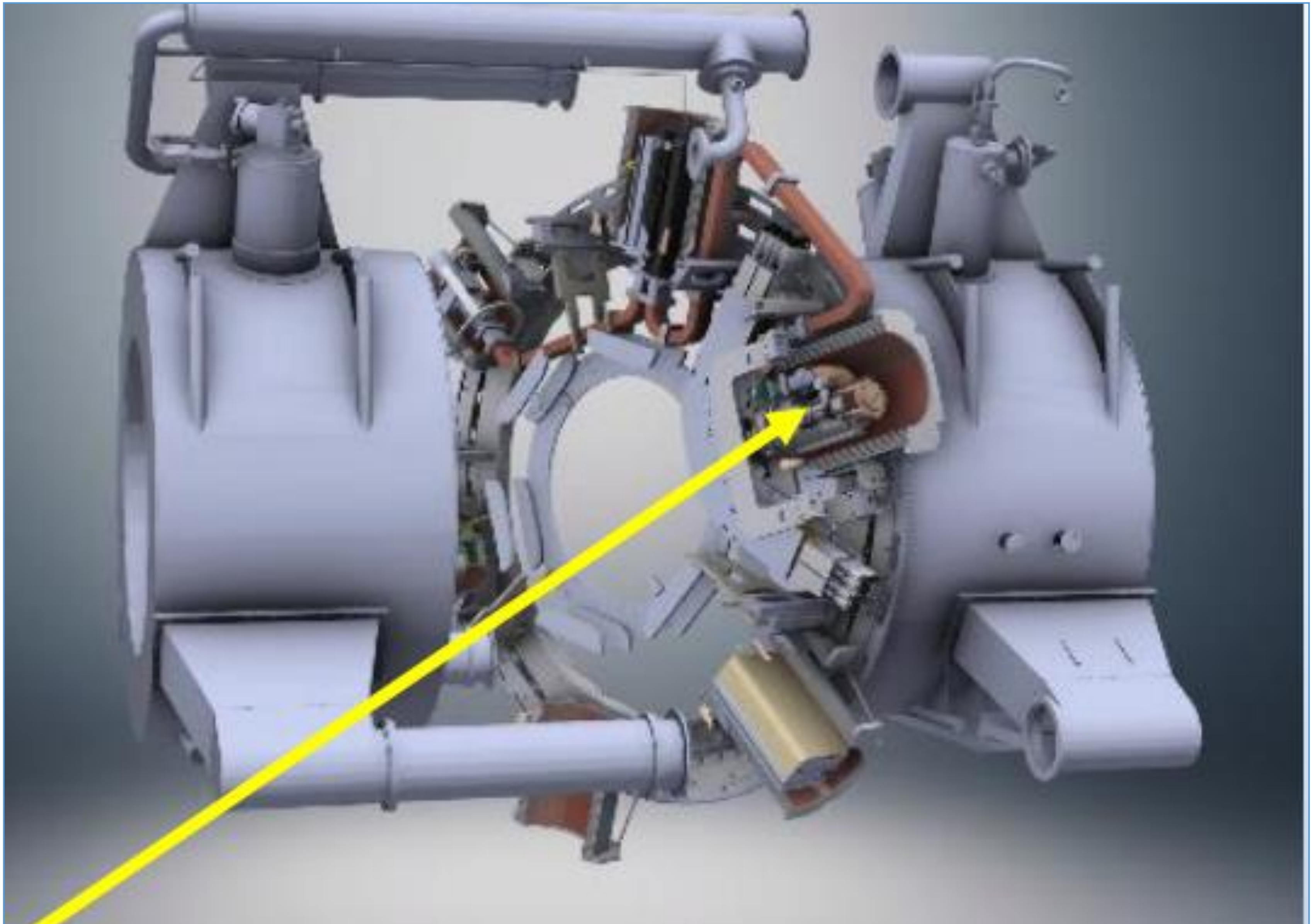
Intra- fraction error corrections

MRI based imaging

- Introduced in 2012 by Viewray – MRIdian (0.35 T MRI with Cobalt 60-RT system; later replaced in 2017 by Linac)

- Elekta Unity 2019

MRIdian



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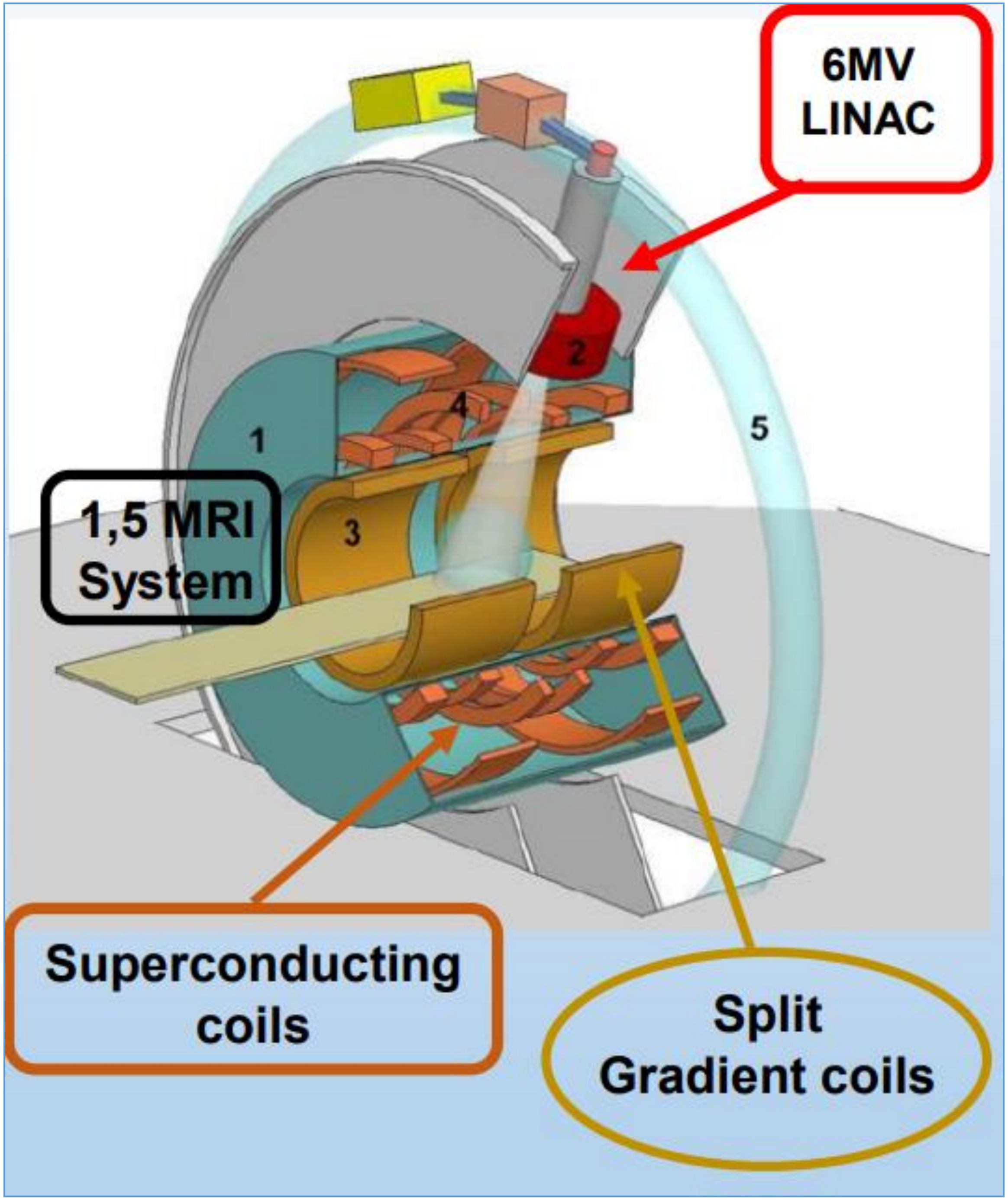
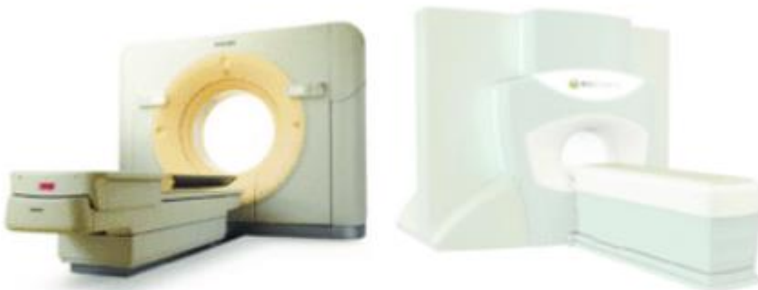

6MV
LINAC
1,5 MRI
System
1
2
3
4
5
Superconducting
coils
Split
Gradient coils

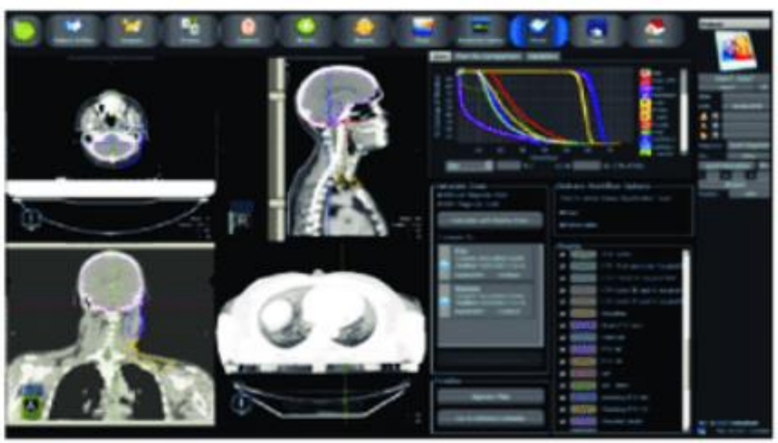
	MRIdian	**Unity**
MRI strength	0.35T	1.5T
Design	Split magnet	Single magnet
Imaging sequence	steady state free precession (SSFP) MRI pulse sequence	Range of sequences, DWI, etc
Gating	Automatic gating	Yes, previously no

Workflow of MR guided Adaptive RT

Planning



CT/MR simulation and reference planning



Treatment

Patient arrives for daily Tx, position on table

↓

Scan daily MR image (2 min)

↓

Rigid registration between daily MR and reference images (2 min)

↓

Create daily adaptive treatment plan (re-contour 10 min, re-optimization 5 min)

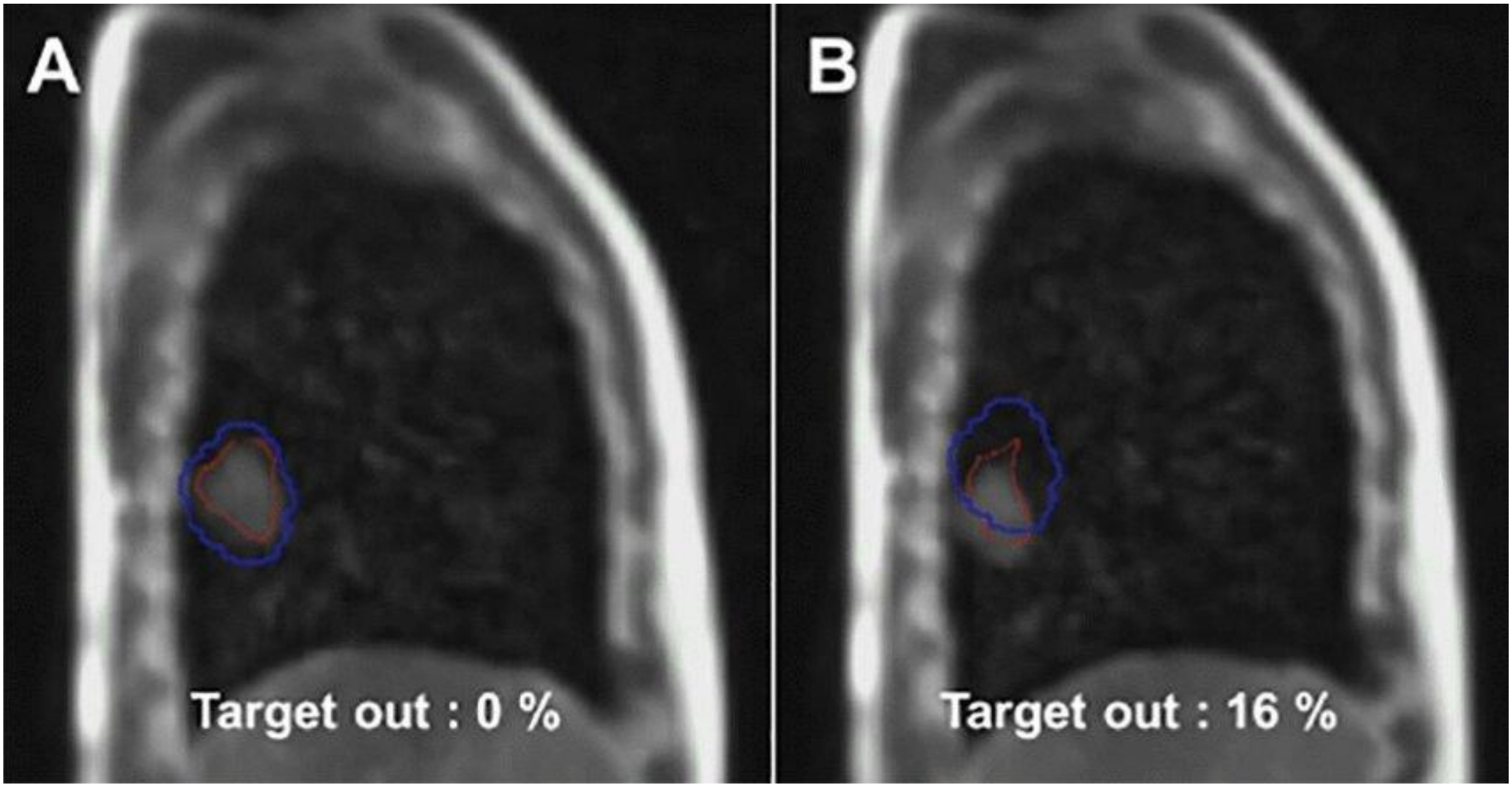
↓

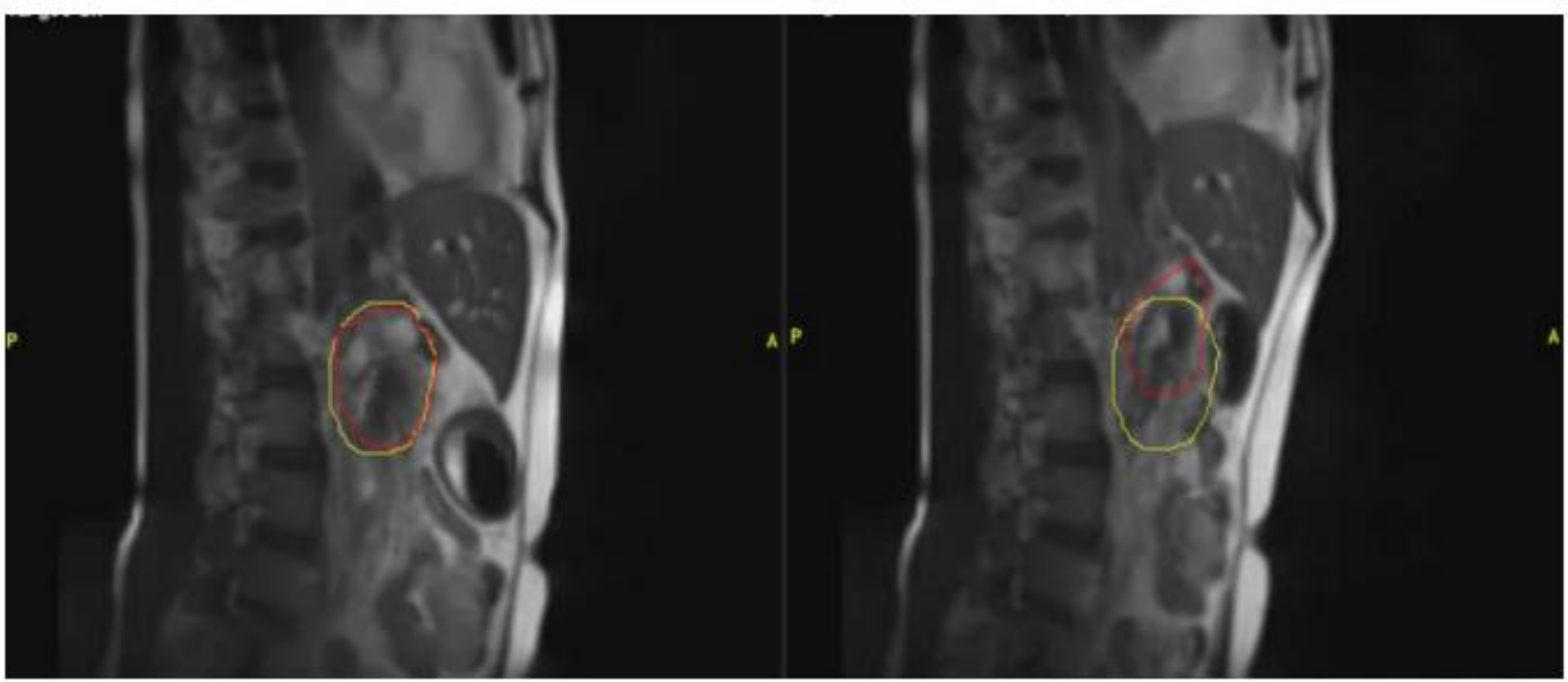
Treatment delivery

Will enable tighter margins, dose escalation with favourable toxicity profile

MRI based gating

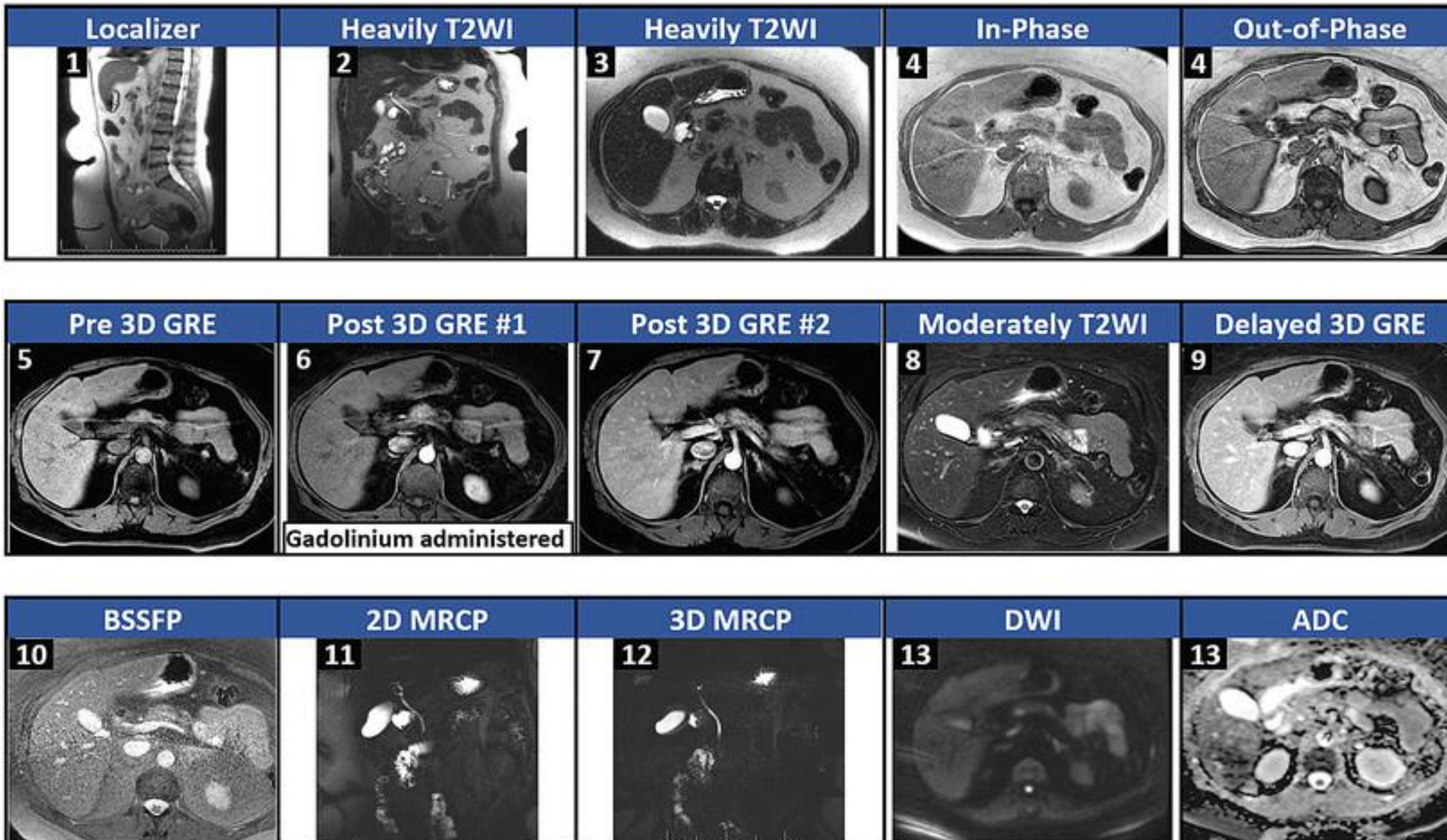
Real-time imaging of soft tissues enables visualization with high accuracy the target during treatment course and provides the ability to monitor in real time the physiologic moments of internal organs that impact on intra-fraction reproducibility of dose delivery


A
Target out : 0 %
B
Target out : 16 %


P
A
P
A

Imaging sequence options-

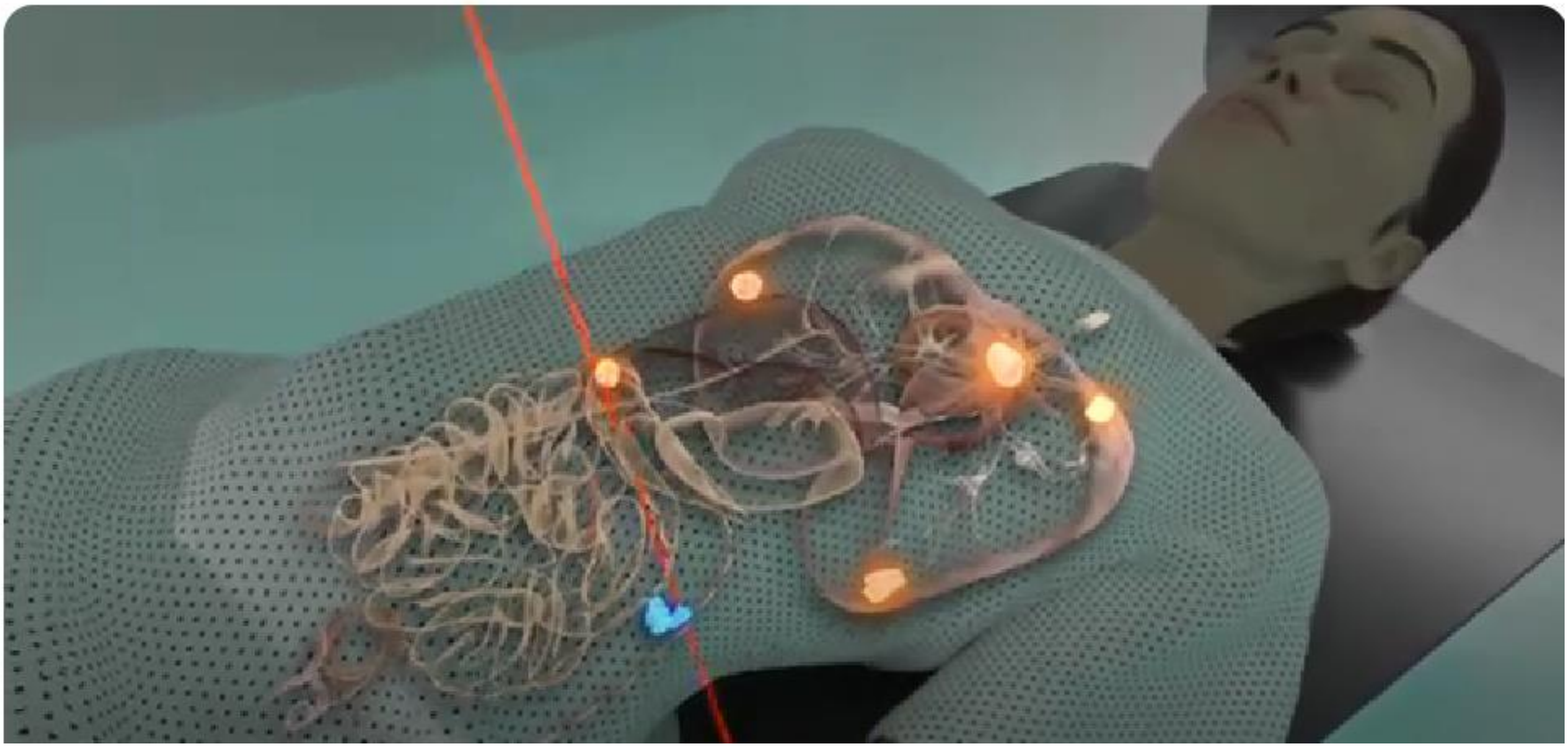
compared to CT- much better visibility



ADVANTAGES

- The improved soft tissue imaging over CBCT scanning obviates the need for implanted markers.
- Clear view of the tumor and surrounding organs facilitates smaller safety margins.
- Software makes it possible to adapt the treatment plan to the anatomy of the day.
- The tumor and organs around it can be visualized continuously during the delivery of the beam. This enables a more precise tracking of the delivered dose, but also the ability to shut down the beam immediately if unfavorable conditions occur during the treatments
- In future, biological dose painting!

PET based RT



Biology guided IGRT

- Molecular/ biological/ functional imaging

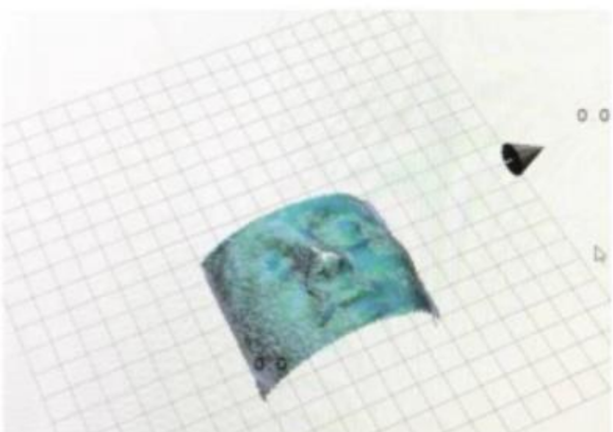
- enables the visualization of various biological pathways and physiological characteristics of tumors and/or normal tissues.

- Heterogeneity in tumour biology has established concept of dose escalation selectively- dose painting

- To tackle with tumor burden or tumor cell density, tumor cell proliferation, and tumor hypoxia

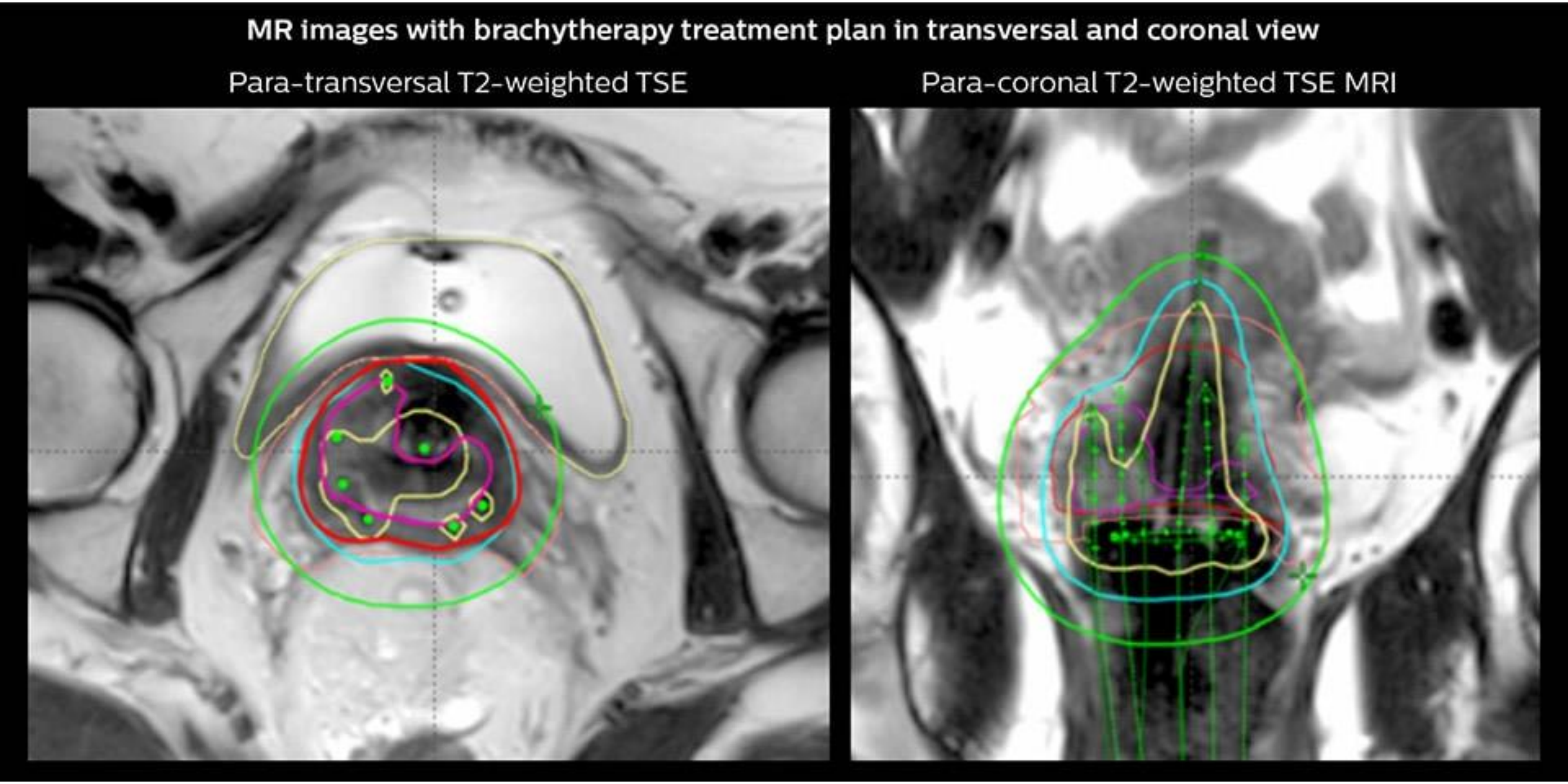
SGRT

(d)



(e)

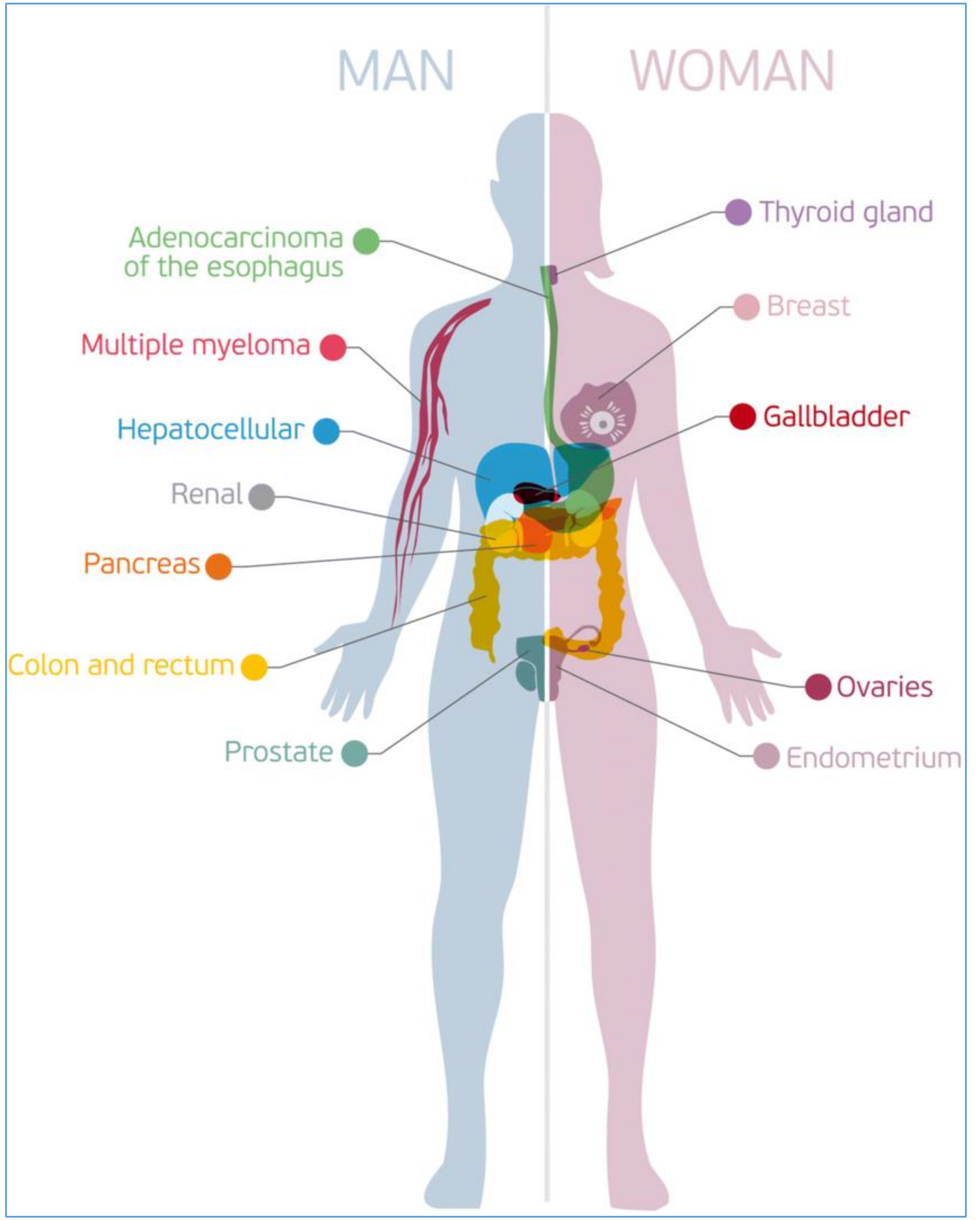
Image guided Brachytherapy



WAIT BUT WHY

Surrogates for toxicity

- Reduced margins
- Adapting to newer anatomy
- Better visibility



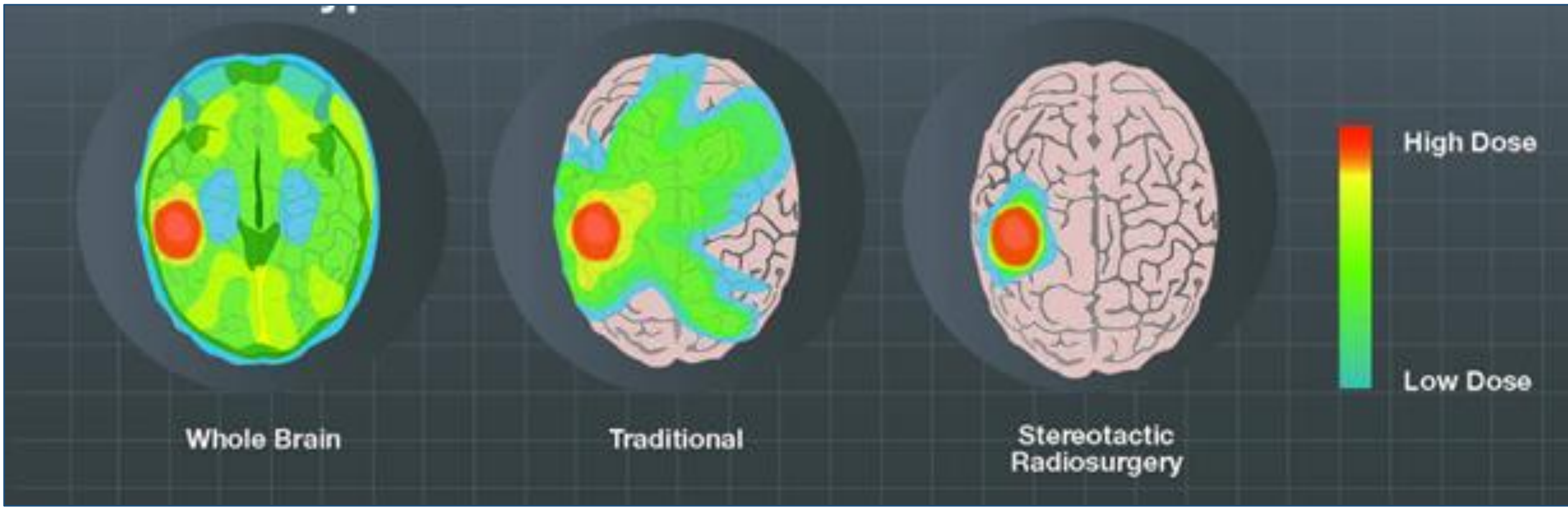
Castelli *et al. Radiation Oncology* (2015) 10:6
DOI 10.1186/s13014-014-0318-z

RADIATION ONCOLOGY

RESEARCH **Open Access**

Impact of head and neck cancer adaptive radiotherapy to spare the parotid glands and decrease the risk of xerostomia

Joel Castelli[1,2,3*], Antoine Simon[2,3], Guillaume Louvel[1], Olivier Henry[1], Enrique Chajon[1], Mohamed Nassef[2,3], Pascal Haigron[2,3], Guillaume Cazoulat[2,3], Juan David Ospina[2,3], Franck Jegoux[4], Karen Benezery[5] and Renaud de Crevoisier[1,2,3]



Whole Brain
Traditional
Stereotactic Radiosurgery
High Dose
Low Dose

Advances in Radiation Oncology (2020) 5, 369-376

advances in radiation oncology

www.advancesradonc.org

Scientific Article

IMRT Reduces Acute Toxicity in Patients Treated With Preoperative Chemoradiation for Gastric Cancer

Shalini Moningi, MD,[a] Jaffer A. Ajani, MD,[b] Brian D. Badgwell, MD,[c]

- The rate of grade 3 to 4 acute toxicity was significantly lower in patients treated with IMRT compared with 3DCRT.
- The composite rate of toxicity-related events (hospitalization, feeding tube use, intravenous rehydration, or radiation therapy breaks) was also significantly lower in patients treated with IMRT compared with 3DCRT.

Clinical Trial > J Clin Oncol. 2021 Nov 20;39(33):3682-3692. doi: 10.1200/JCO.20.02530. Epub 2021 Sep 10.

Late Toxicity After Adjuvant Conventional Radiation Versus Image-Guided Intensity-Modulated Radiotherapy for Cervical Cancer (PARCER): A Randomized Controlled Trial

Supriya Chopra [1], Sudeep Gupta [2], Sadhana Kannan [3], Tapas Dora [4], Reena Engineer [5], Akshay Mangaj [5], Amita Maheshwari [6], T Surappa Shylasree [6], Jaya Ghosh [2], Siji N Paul [1], Reena Phurailatpam [1], Mayuri Charnalia [1], Mitali Alone [7], Jamema Swamidas [1], Umesh Mahantshetty [5], Kedar Deodhar [8], Rajendra Kerkar [6], Shyam K Shrivastava [5]

JAMA Oncology | Original Investigation

Magnetic Resonance Imaging–Guided vs Computed Tomography–Guided Stereotactic Body Radiotherapy for Prostate Cancer

The MIRAGE Randomized Clinical Trial

Amar U. Kishan, MD; Ting Martin Ma, MD, PhD; James M. Lamb, PhD; Maria Casado, BS; Holly Wilhalme, MSc; Daniel A. Low, PhD;
Ke Sheng, PhD; Sahil Sharma, BS; Nicholas G. Nickols, MD, PhD; Jonathan Pham, PhD; Yingli Yang, PhD;
Yu Gao, PhD; John Neylon, PhD; Vincent Basehart, BS; Minsong Cao, PhD; Michael L. Steinberg, MD

Findings In this phase 3 randomized clinical trial of 156 patients with prostate cancer, MRI guidance significantly reduced acute moderate physician-scored genitourinary and gastrointestinal toxic effects and led to smaller decrements in patient-reported urinary and bowel function.


THANK
YOU!