SBRT: management of respiratory motion

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Index

Lung mobility

4D CT for target definition

IGRT

Tumor and MLC tracking

SBRT vs standard RT in lung

Not only breathing motion

Take home messages

Monet –Rouen cathedral, 1893/94

Influence of organ motion

The North American Experience with Stereotactic Body Radiation Therapy in Non-small Cell Lung Cancer

Robert D. Timmerman, MD, Clint Park, MD,* and Brian D. Kavanagh, MD, MPH†*

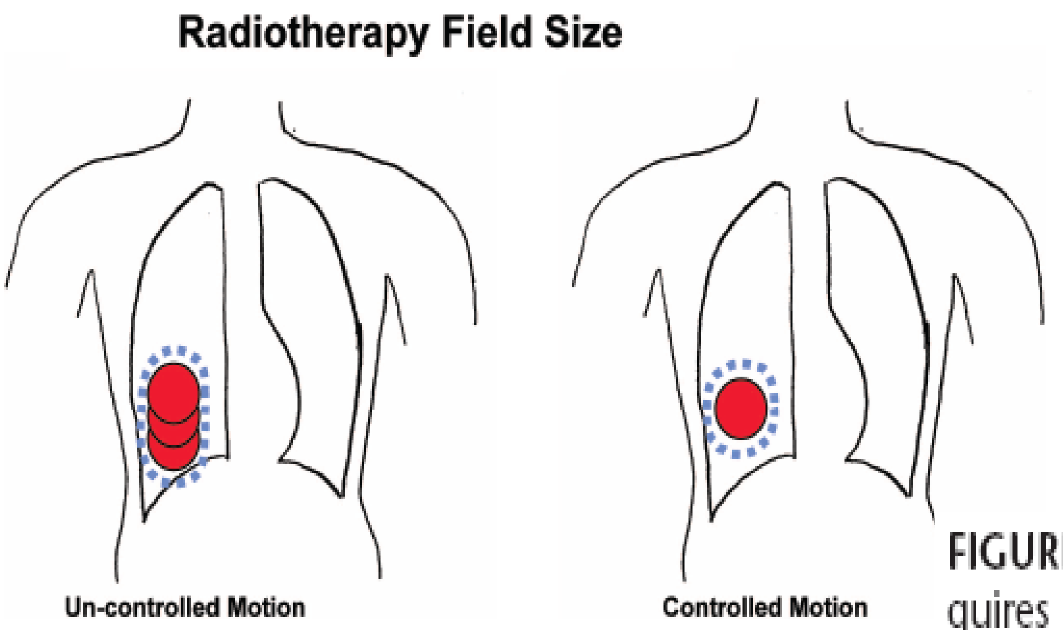

FIGURE 2. Uncontrolled tumor motion requires enlargement of a beam's eye view radiation portal to avoid target inaccuracy. Careful assessment and control of motion dramatically decrease normal tissue exposure.

Influence of organ motion in thorax

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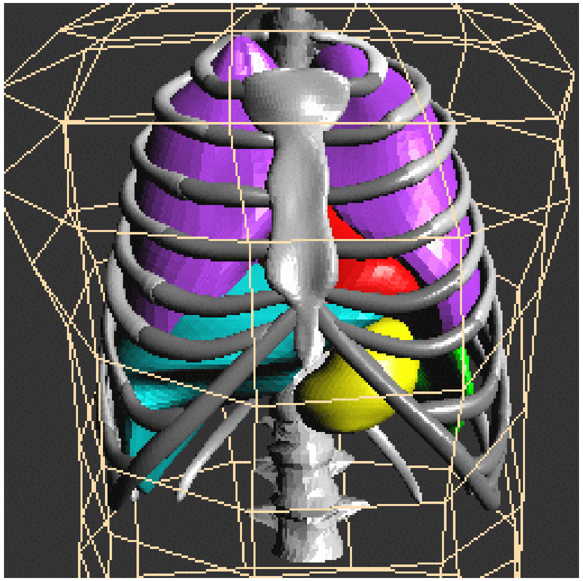
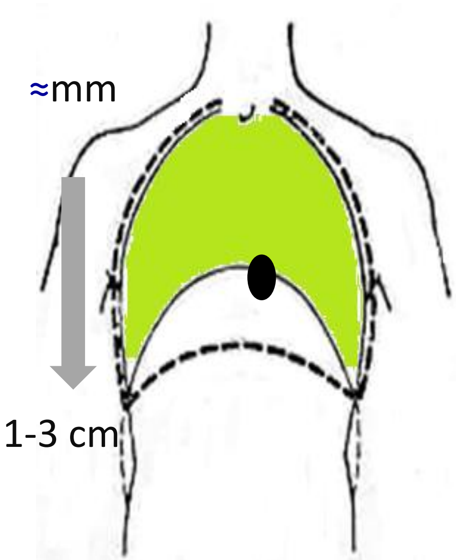
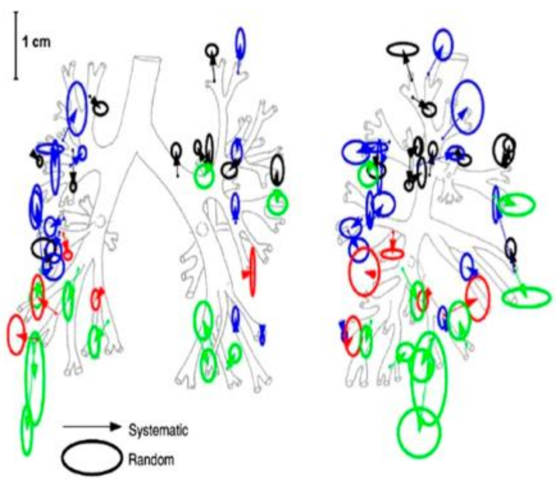


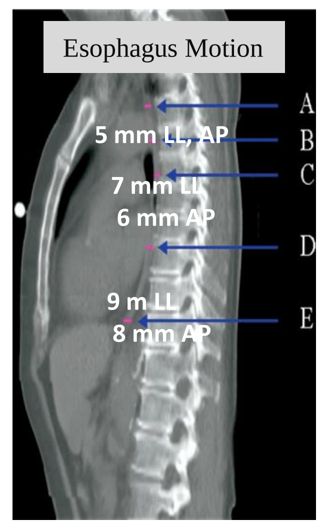
Structure	Mean excursion (mm) (range)		
	Free breathing		
	SI	AP	ML
Lungs	10.3 (1–31.9)	6.4 (0–24.4)	(1–10)
Diaphragm	14.9 (2.6–38.2)		
Liver	12.3 (4.9–30.4)	(max. 5.2)	(max. 4.6)
Chest wall	7.3 (2–15)	2.3 (0–8)	(5–7)
Heart	18.1 (12–25)	2.4	

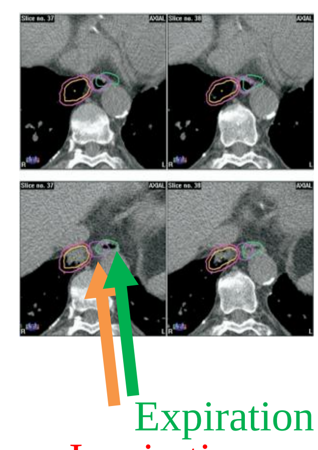
Korreman BJR 2015





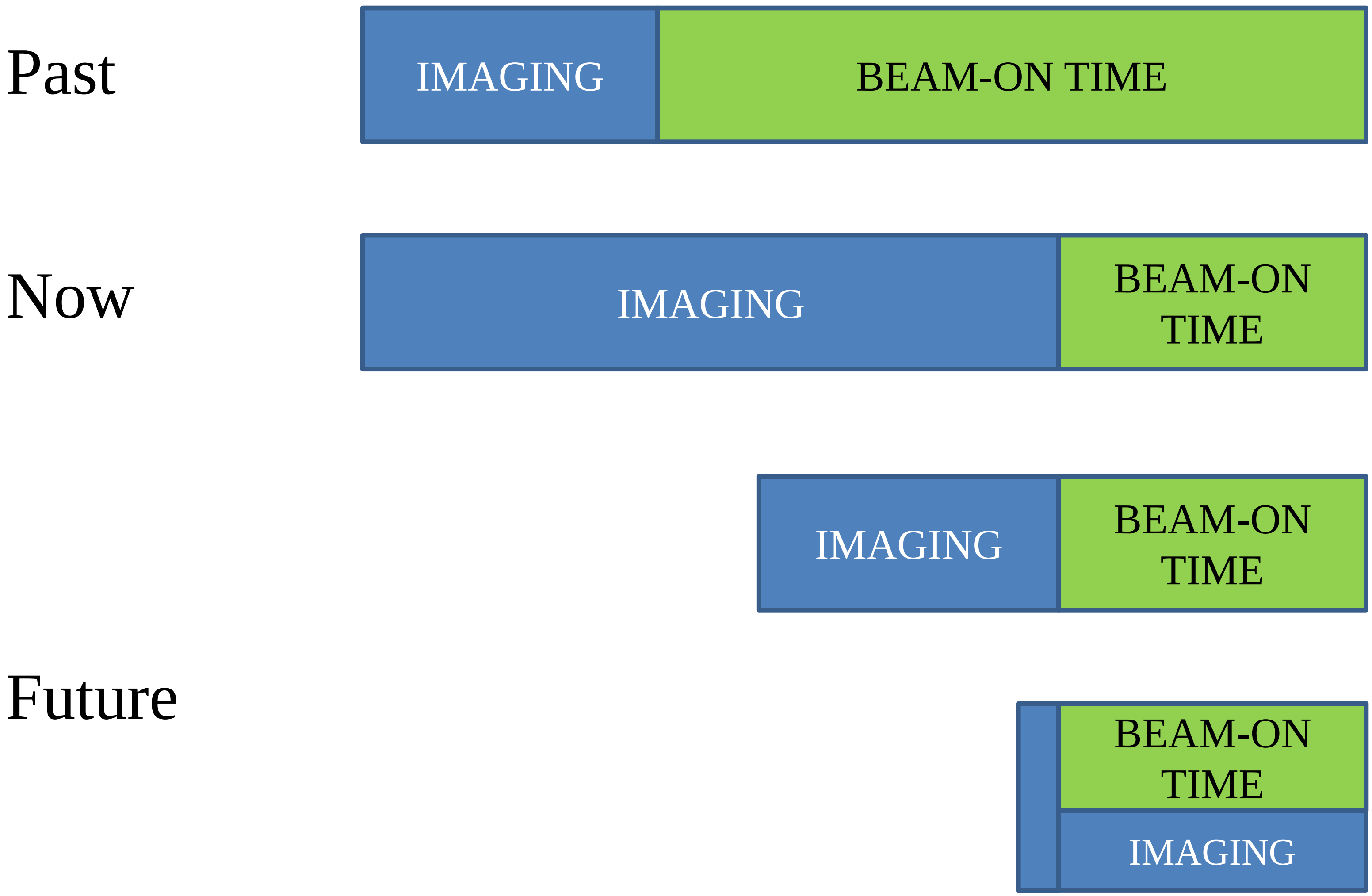
Sonke IJROBP 2008





Dieleman et al. IJROBP 2007

SBRT efficiency



Slotman, ESTRO 2011

Rationale for motion management

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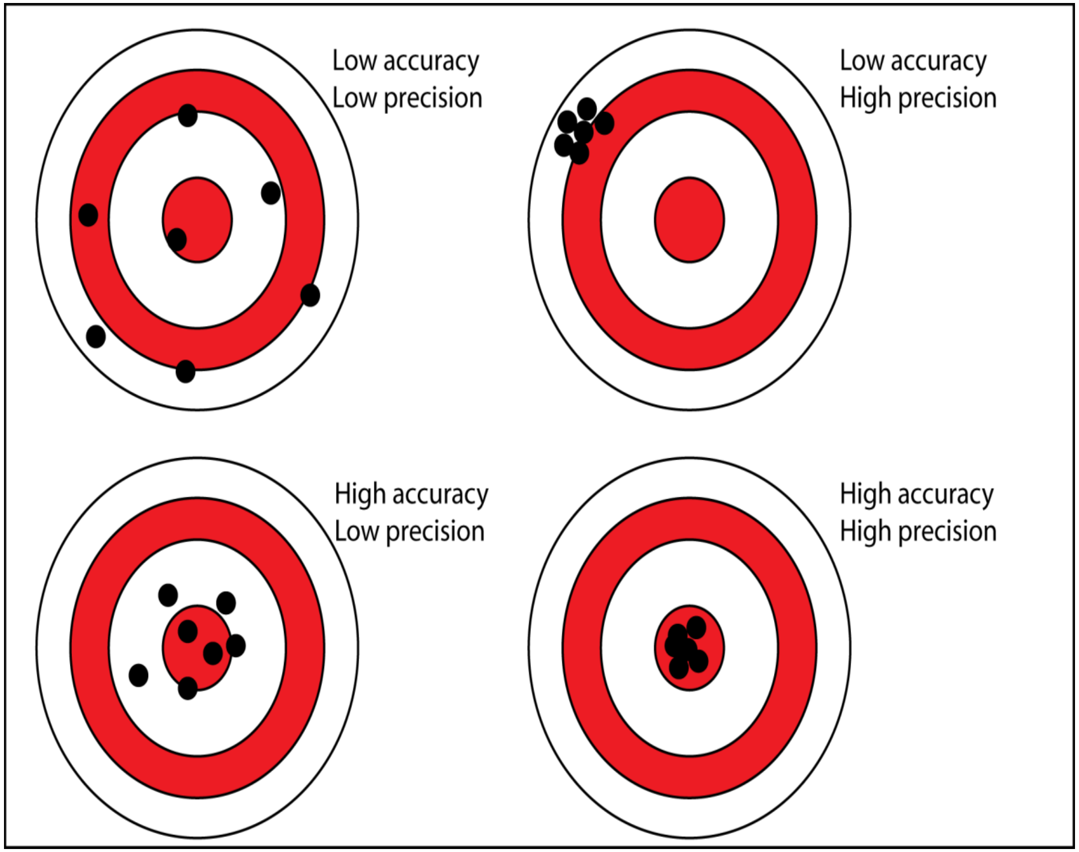
Highly conformal radiation techniques (SBRT):

- high precision
- risk for geographical miss

Control for:

- Patient set-up errors
- Organ motion
- Patient movement



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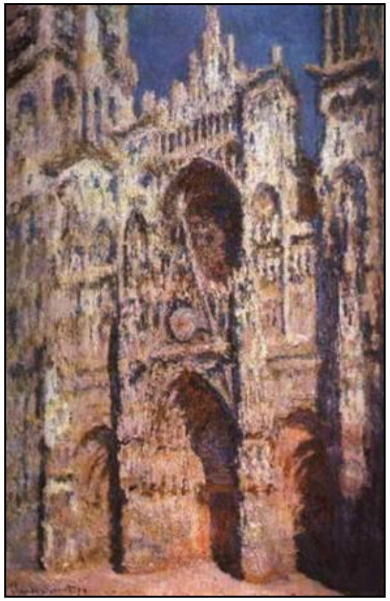

Monet –Rouen cathedral, 1893/94

4D SBRT

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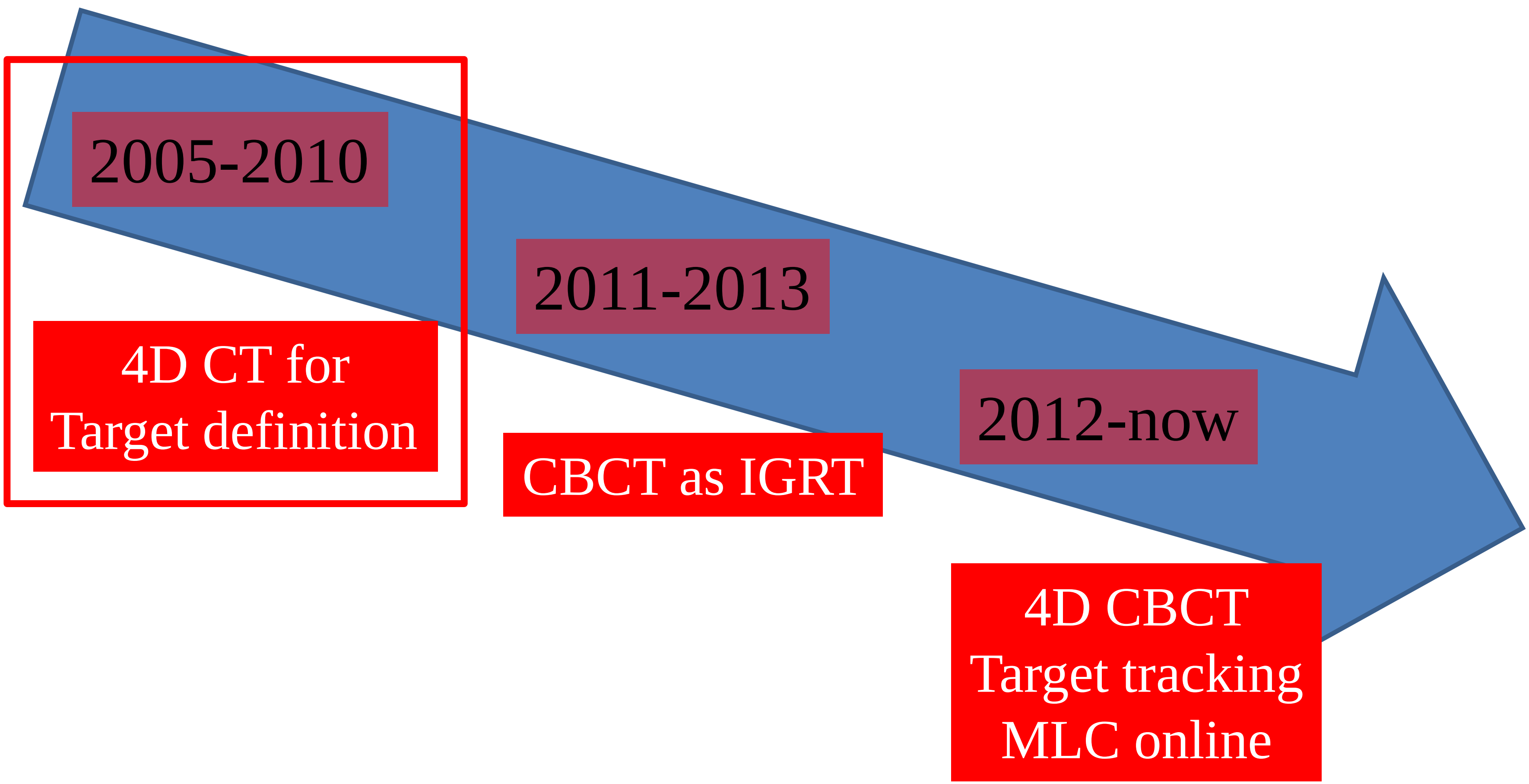
Search results
Items: 1 to 20 of 112 | 4D SBRT

Search results
Items: 1 to 20 of 88 | 4D SBRT lung



Target definition expansion

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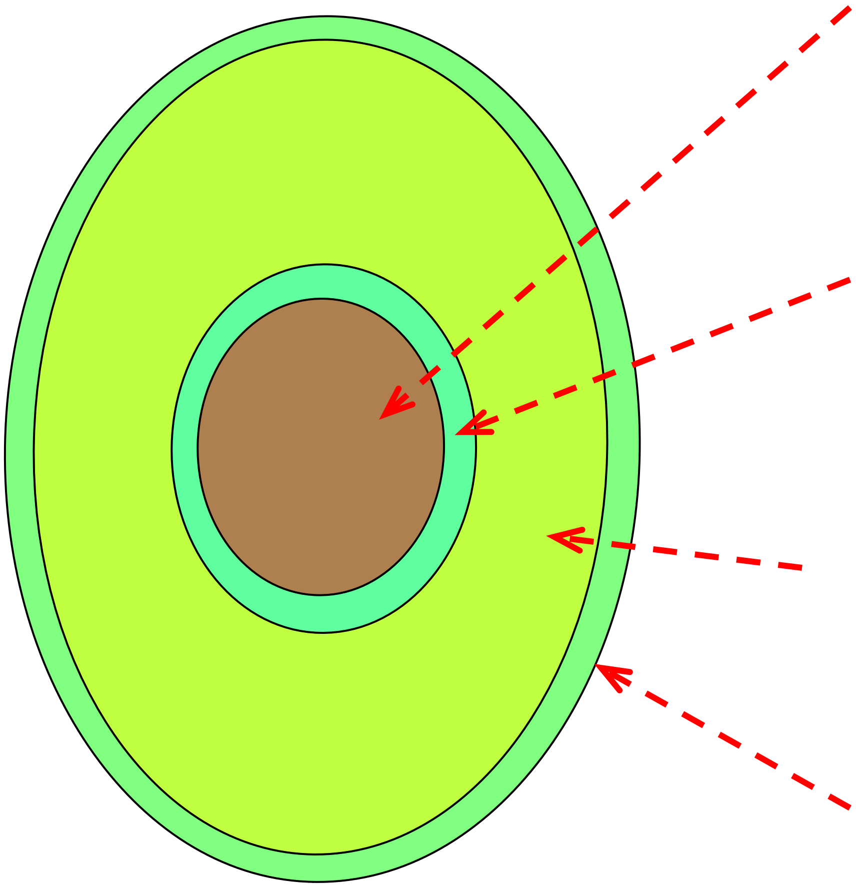

Gross Tumor Volume (GTV)

Biological Target Volume (BTV)

Clinical Target Volume (CTV)
Espansione per la micromalattia

Internal Target Volume (ITV)
Movimento del tumore

Setup Margin (SM)
Margini di posizionamento

4D-CT

4D-CT for target definition

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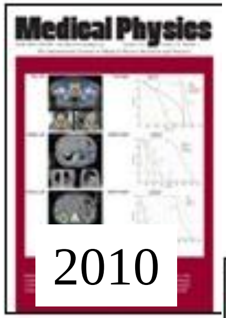
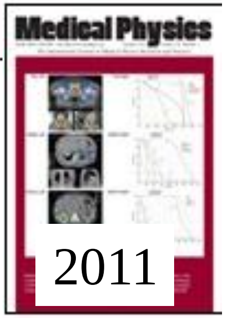


Med. Phys. 37 (9), September 2010

Semiautomatic technique for defining the internal gross tumor volume of lung tumors close to liver/spleen cupola by 4D-CT[a)]

Pietro Mancosu[b)]
Department of Radiotherapy, IRCCS Istituto Clinico Humanitas, Rozzano, 20089 Milano, Italy

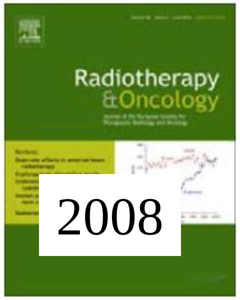


Med. Phys. 38 (1), January 2011

Semiautomatic method to identify the best phase for gated RT in lung region by 4D-PET/CT acquisitions[a)]

Pietro Mancosu[b)]
Department of Radiotherapy, IRCCS Istituto Clinico Humanitas, Rozzano, 20089 Milano, Italy

Radiotherapy and Oncology 87 (2008) 339–342



Contrast enhanced 4D-CT imaging for target volume definition in pancreatic ductal adenocarcinoma

Pietro Mancosu[a,*], Valentino Bettinardi[a], Paolo Passoni[a], Simone Gusmini[a,b],

Journal of Applied Clinical Medical Physics, Vol. 10, No. 4, Fall 2009

4D-PET data sorting into different number of phases: a NEMA IQ phantom study

Pietro Mancosu,[1,a] Roberto Sghedoni,[2] Valentino Bettinardi,[3]

How to evaluate the breathing motion

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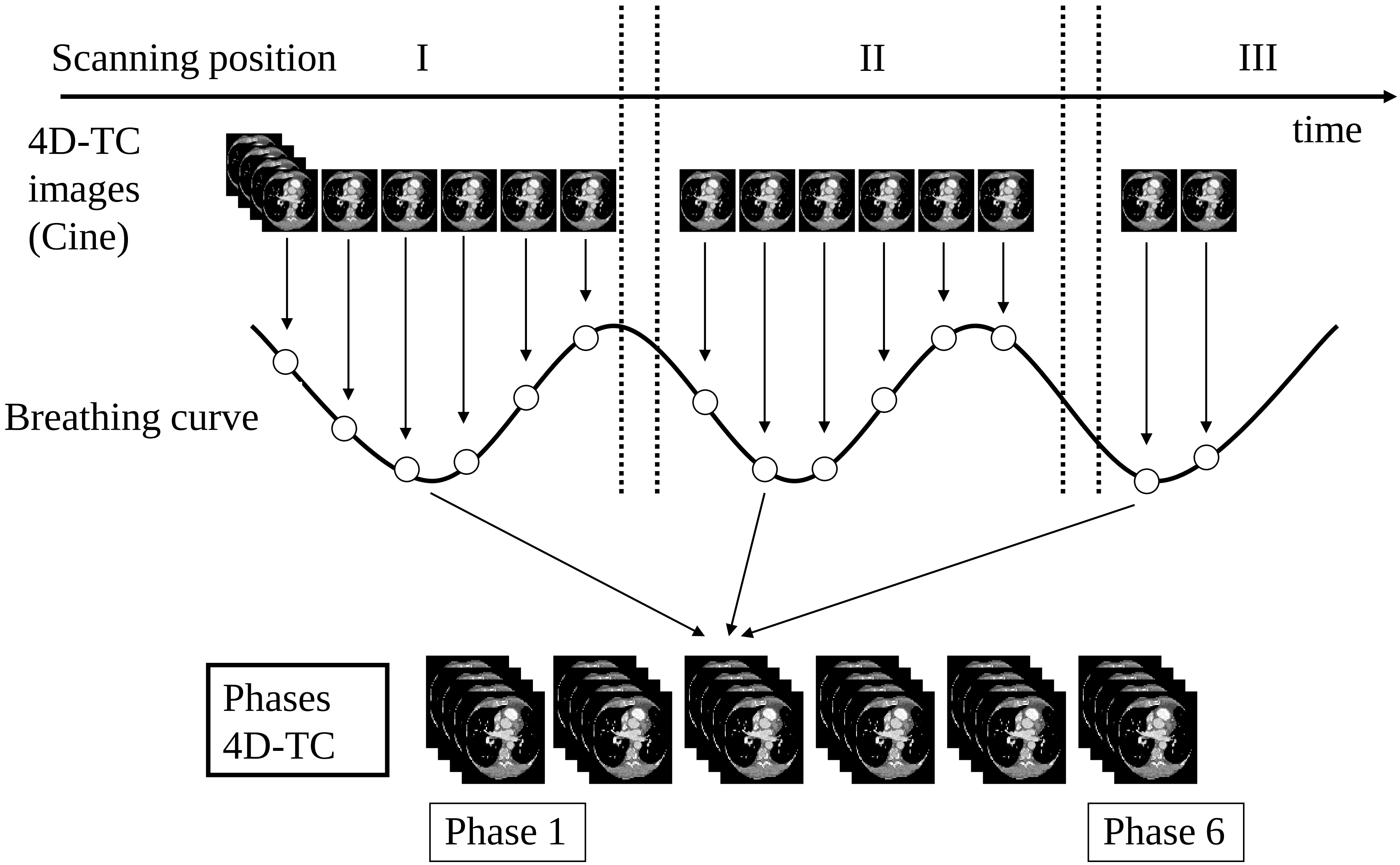
GE Healthcare

Siemens

Philips

4D CT reconstruction



4D CT reconstruction

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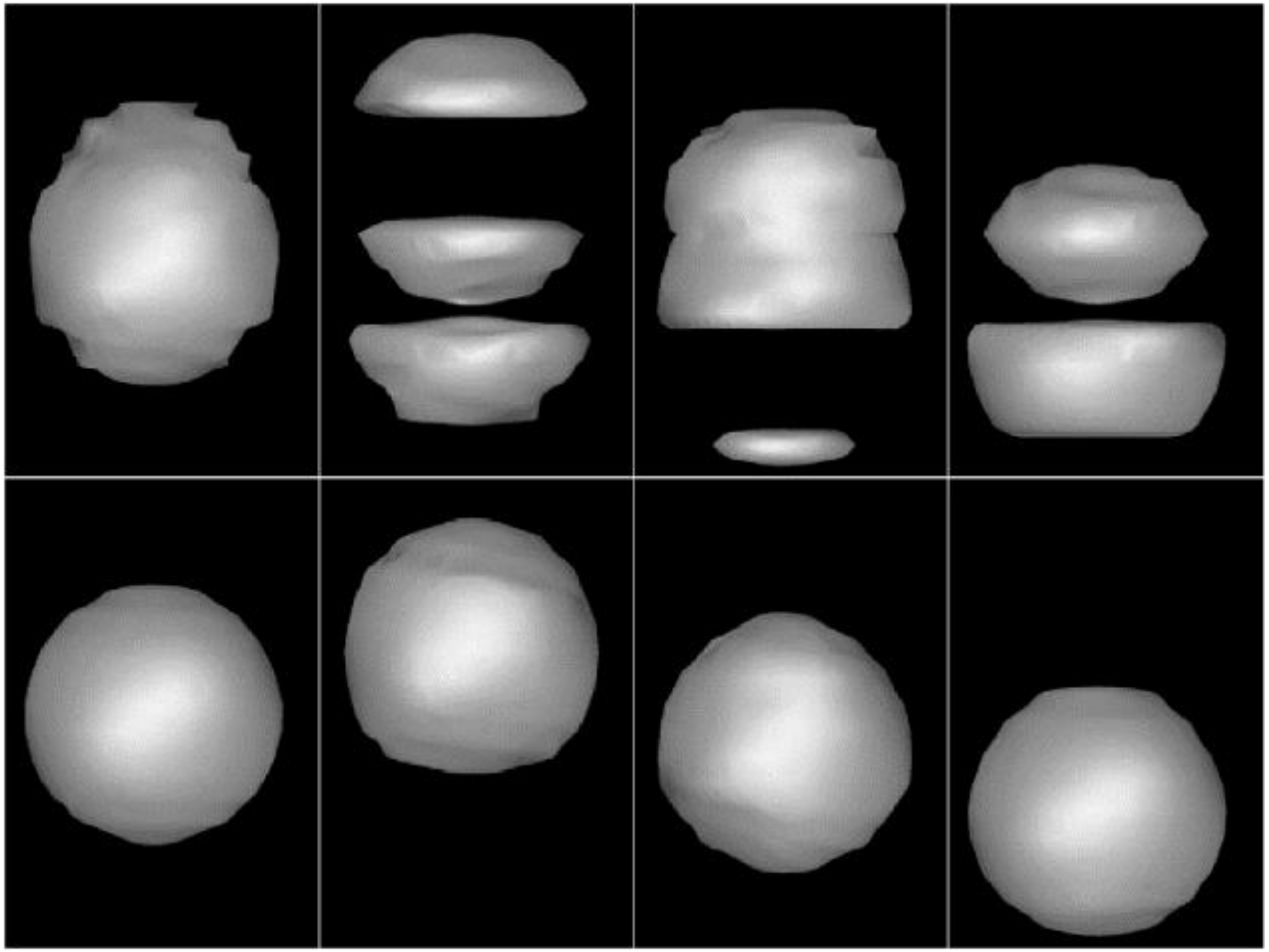
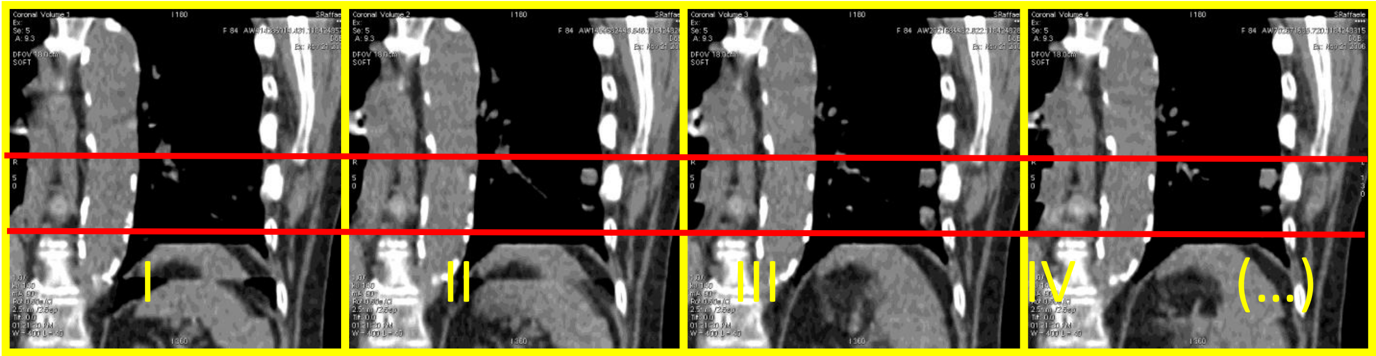
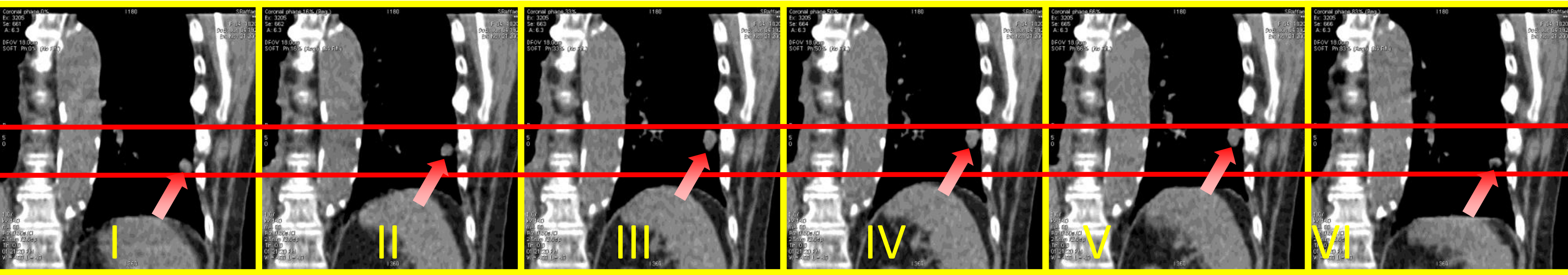


4D CT reconstruction

rotaz.

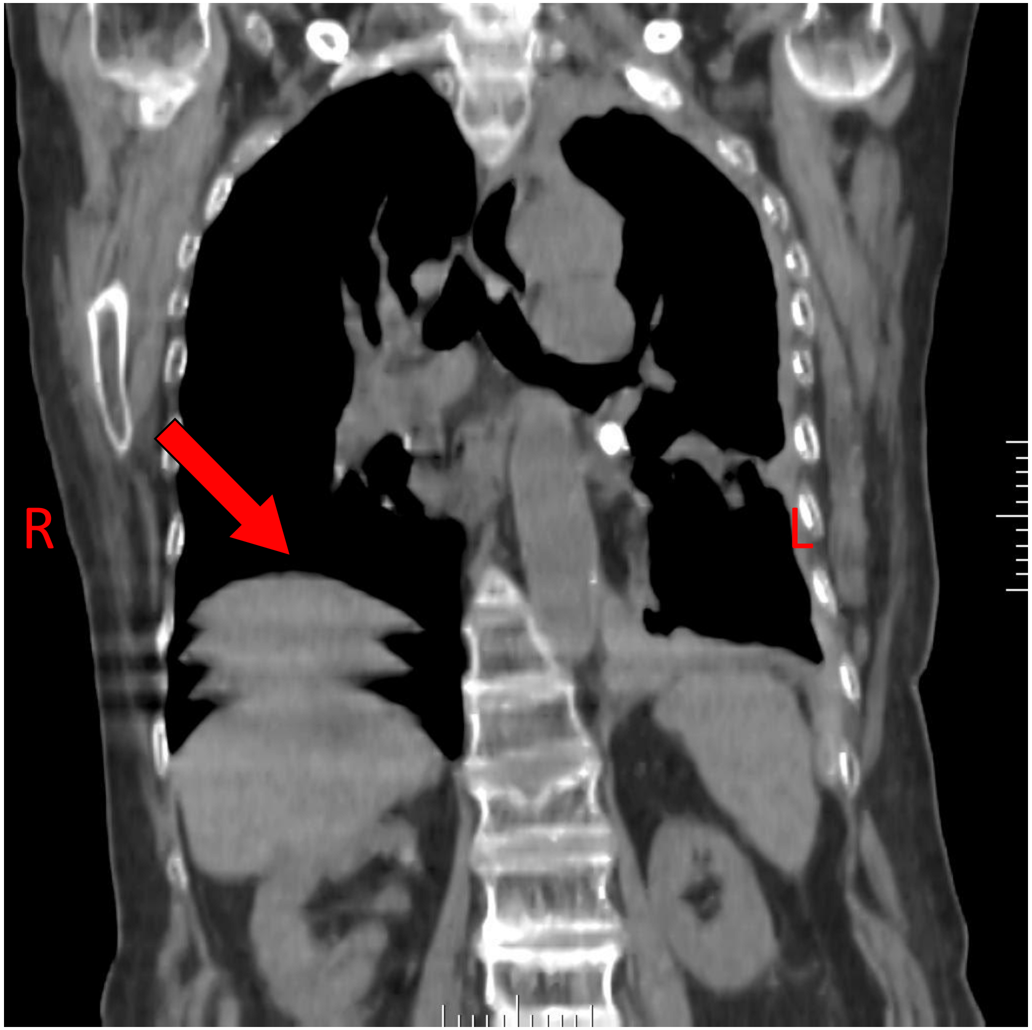




Mancosu Med Phys 2012

4D TC - CONTORNAMENTO

Free breathing CT



4D CT - lung

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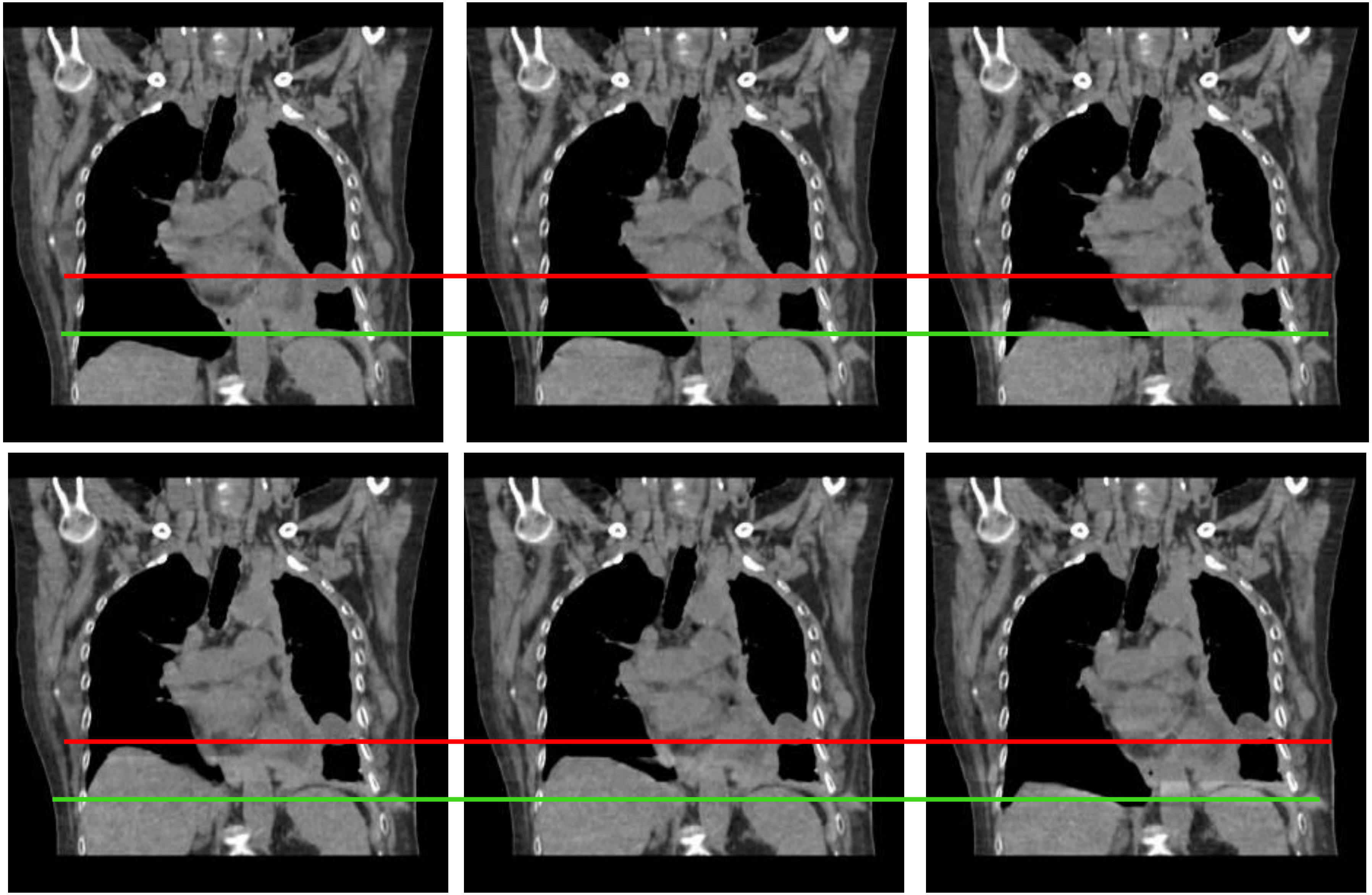
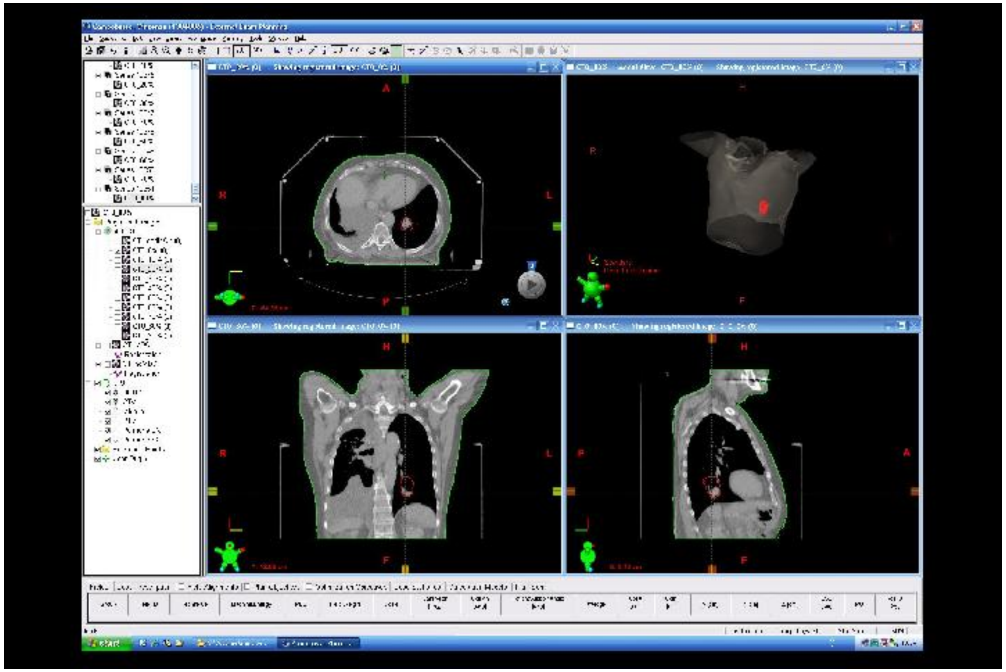
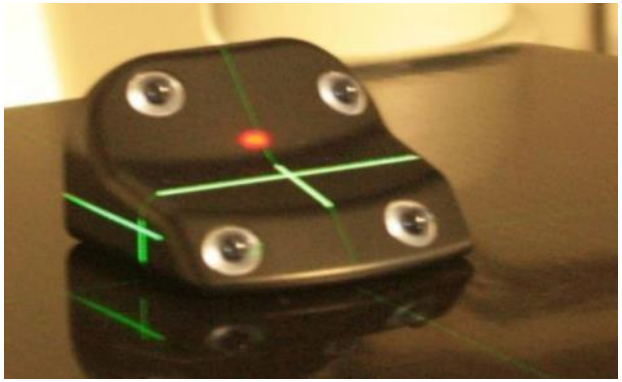


Gating





4D SBRT

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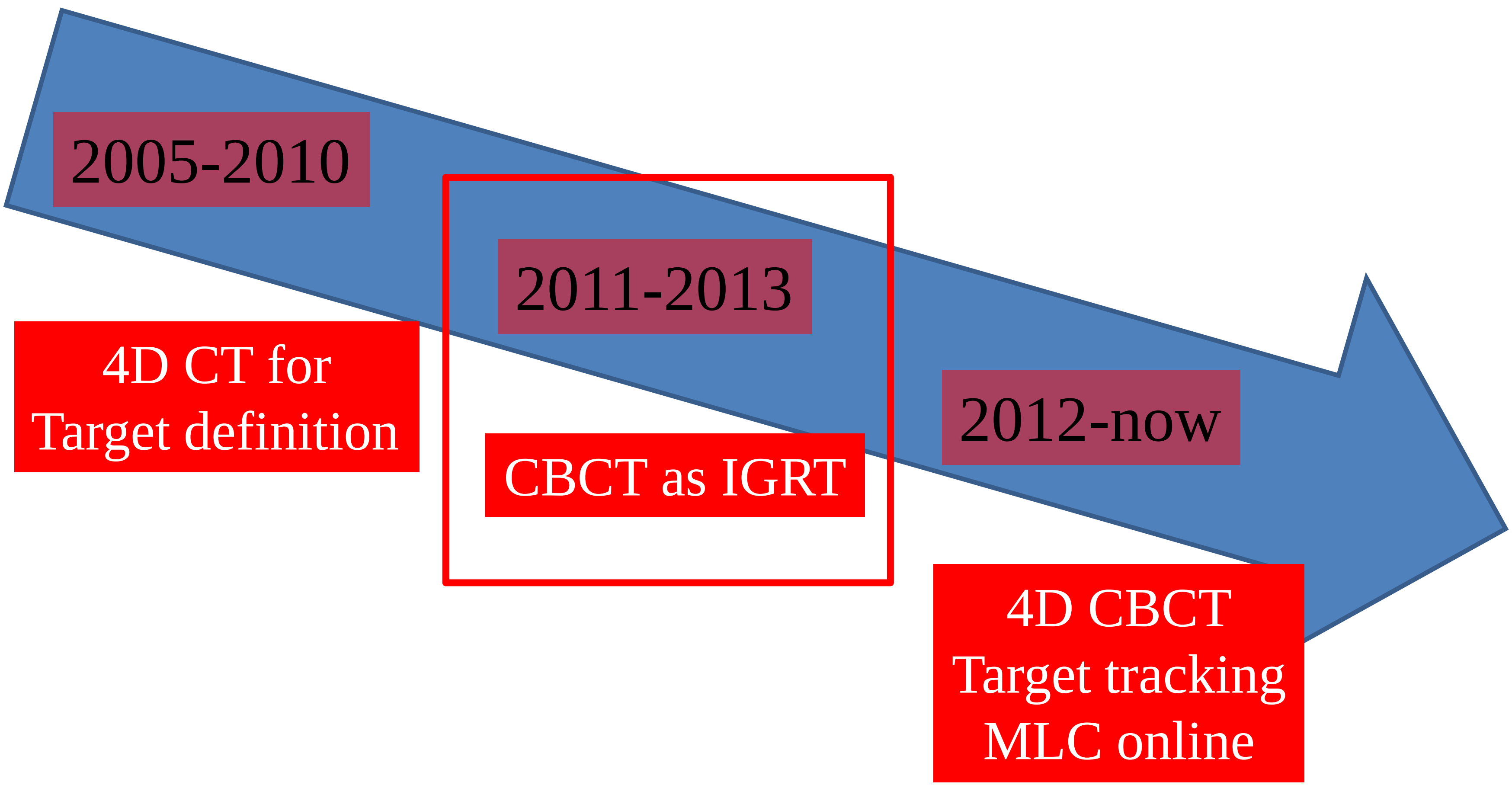

Image Guided RT

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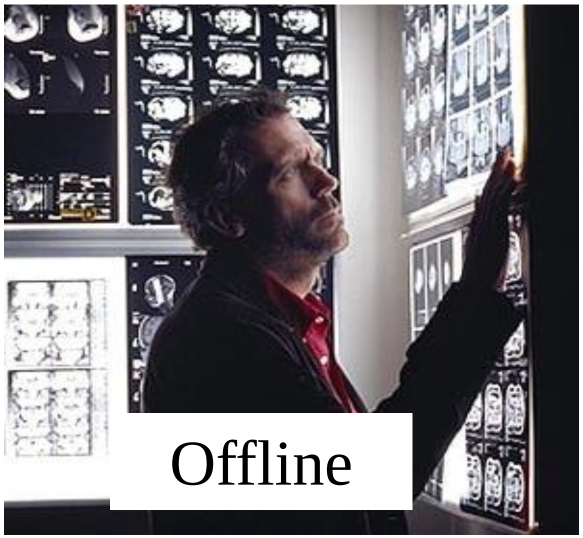
Tools for verifying patient position and adapting treatment plans. Monotoring during beam on time

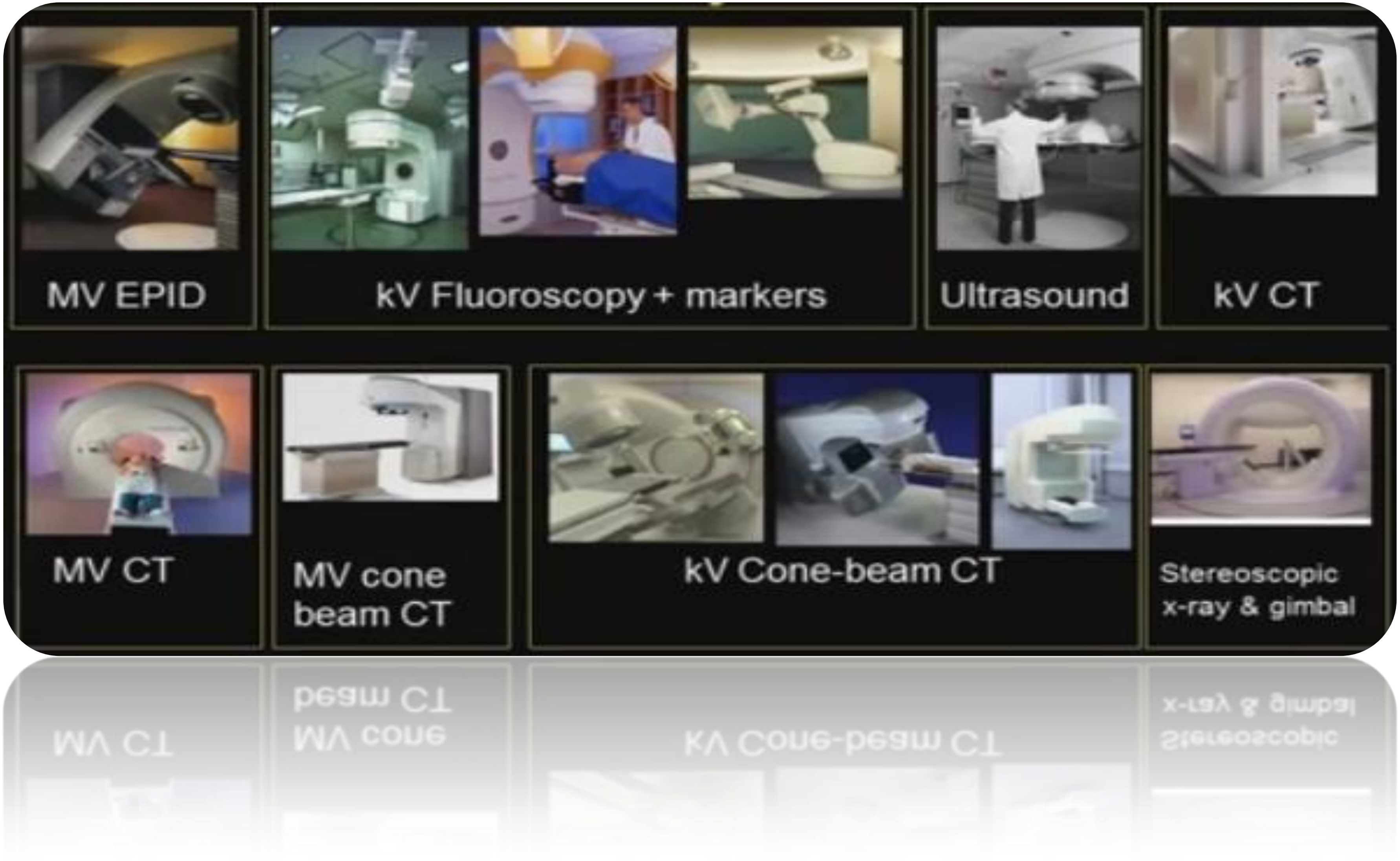


Reduction of PTV margins

Reduction of irradiated volume

Image of Dirk Varellen

Image Guided RadioTherapy

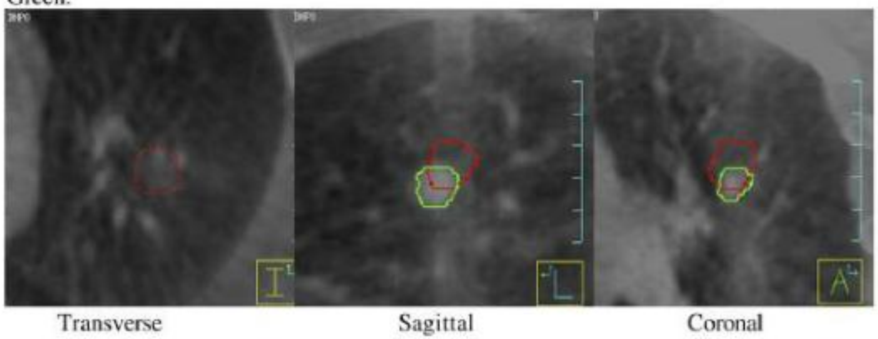


Online IGRT

CLINICAL INVESTIGATION

IMAGE-GUIDED RADIOTHERAPY VIA DAILY ONLINE CONE-BEAM CT SUBSTANTIALLY REDUCES MARGIN REQUIREMENTS FOR STEREOTACTIC LUNG RADIOTHERAPY

GTV position pre-correction: Planning CT GTV in Red; Pre-Correction GTV in Green.



GTV position post-correction: Planning CT GTV in Red; Post-Correction GTV in Blue.

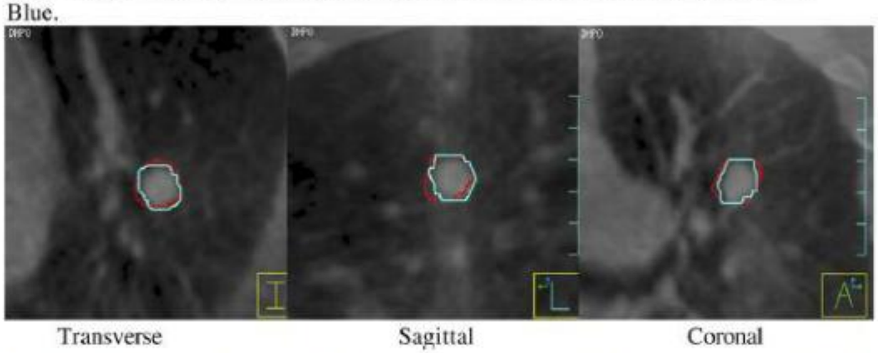
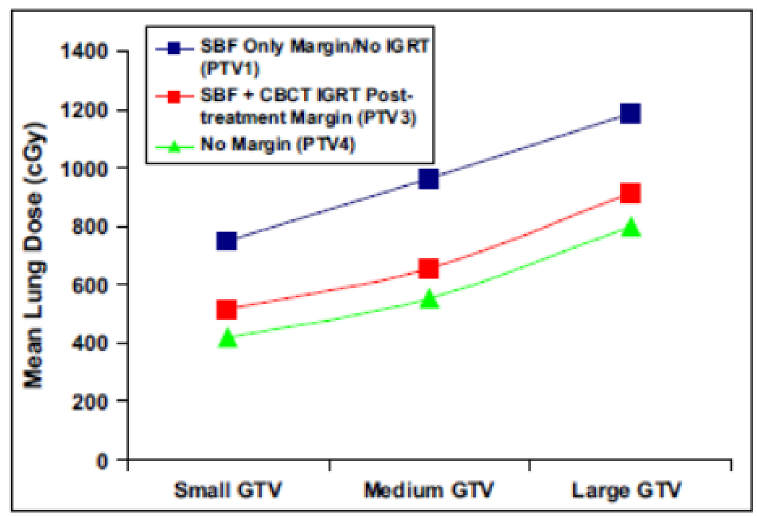


Fig. 1. Precorrection and postcorrection cone-beam CT (CBCT) images for an example protocol patient treated in the stereotactic body frame. (Top) Gross tumor volume (GTV) position precorrection: planning CT GTV in red; precorrection GTV in green. (Bottom) GTV position postcorrection: planning CT GTV in red; postcorrection GTV in blue.

308 CBCT, 24 pts

Tumor positional errors using stereotactic body frame coordinates for setup :
NO IGRT 10-12mm,
YES IGRT <2 mm.



IGRT: how much?

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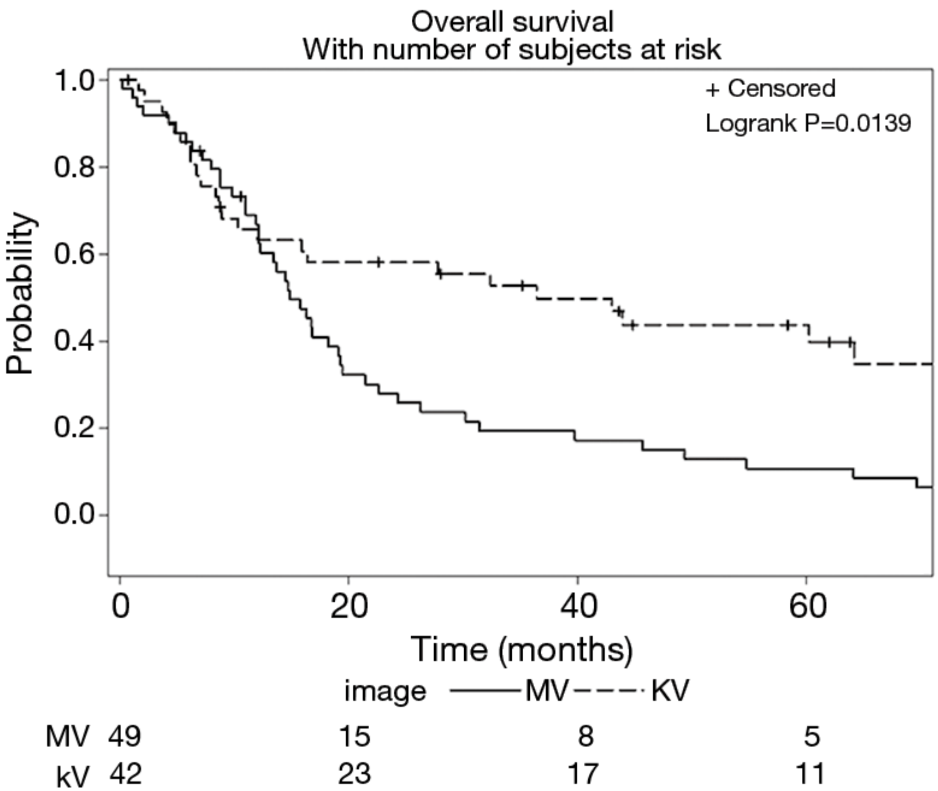
Modern radiotherapy using image guidance for unresectable non-small cell lung cancer can improve outcomes in patients treated with chemoradiation therapy

Matthew P. Deek[1], Sinae Kim[2], Ning Yue[1], Rekha Baby[1], Inaya Ahmed[1], Wei Zou[1], John Langenfeld[3], Joseph Aisner[4], Salma K. Jabbour[1]



Weekly based imaging

Daily based imaging

JTD 2016

JOURNAL OF THORACIC DISEASE

Times are changing fast

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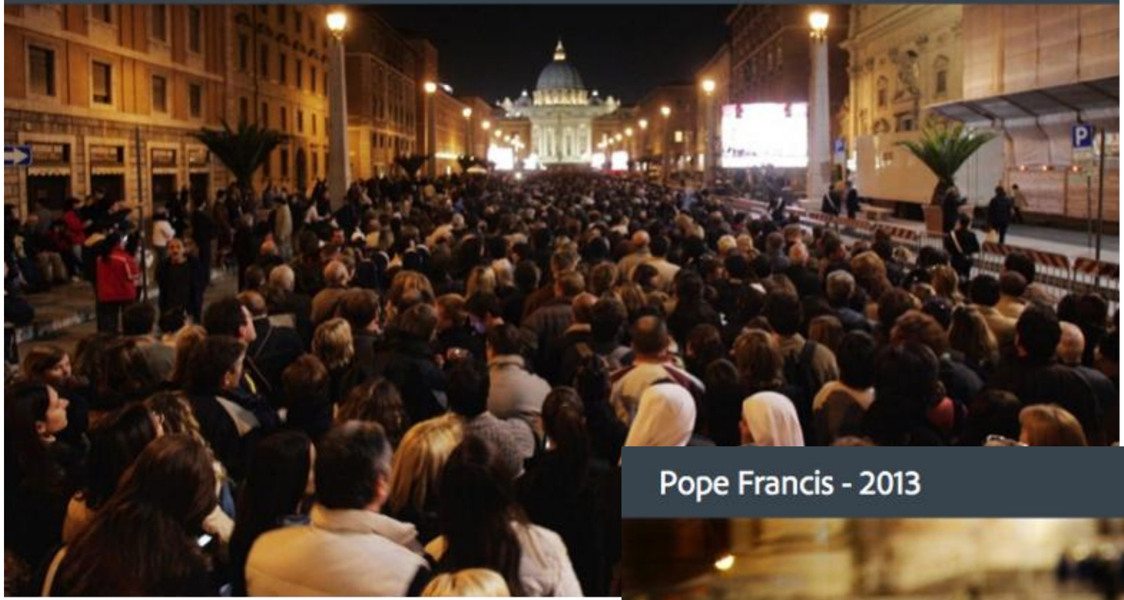
Pope John-Paul - 2005



Pope Francis - 2013

Humanitas experience

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Volumetric modulated arc therapy with flattening filter free (FFF) beams for stereotactic body radiation therapy (SBRT) in patients with medically inoperable early stage non small cell lung cancer (NSCLC)

Pierina Navarria [a,*], Anna Maria Ascolese [a], Pietro Mancosu [a], Filippo Alongi [a], Elena Clerici [a], Angelo Tozzi [a], Cristina Iftode [a], Giacomo Reggiori [a], Stefano Tomatis [a], Maurizio Infante [b], Marco Alloisio [b], Alberto Testori [b], Antonella Fogliata [c], Luca Cozzi [c], Emanuela Morenghi [a], Marta Scorsetti [a]

3DCRT:
Simulation: FB CT
IGRT: MV 2D-2D daily
Delivery: 6MV

VMAT RA:
simulation :4DCT
IGRT: kV-CBCT daily
Delivery: 10FFF

	3DCRT	VMAT RA	*p*
Ipsilateral lung			
V_{5Gy} [%]	31.4 ± 11.9 [6.6–57.8]	25.3 ± 11.8 [6.8–54.0]	0.03
V_{10Gy} [%]	22.6 ± 9.9 [0.0–45.6]	16.4 ± 8.9 [3.8–46.0]	0.007
V_{20Gy} [%]	11.8 ± 7.0 [0.0–26.7]	7.3 ± 4.9 [1.2–26.6]	0.002
MLD [Gy]	7.2 ± 3.0 [0.9–12.6]	4.9 ± 2.4 [1.2–13.3]	<0.001
Contralateral lung			
V_{5Gy} [%]	2.9 ± 4.8 [0.0–18.7]	2.0 ± 3.0 [0.0–11.3]	0.31
V_{10Gy} [%]	0.6 ± 2.5 [0.0–13.3]	0.0 ± 0.2 [0.0–0.9]	0.19
V_{20Gy} [%]	0.1 ± 0.6 [0.0–3.5]	0.0 ± 0.0 [0.0–0.0]	0.31
MLD [Gy]	0.8 ± 0.8 [0.1–3.5]	1.0 ± 0.5 [0.1–2.6]	0.38

	Control at 12 months			
	CT scan		CT–PET	
	3DCRT	RA	3DCRT	RA
PD	6 (7%)	0	6 (10%)	0
SD	16 (20%)	2 (5%)	4 (6.5%)	0
PR	40 (49%)	2 (5%)	33 (53%)	0
CR	20 (24%)	36 (90%)	$\boxed{19\ (31\%)}$	$\boxed{34\ (100\%)}$

4D SBRT

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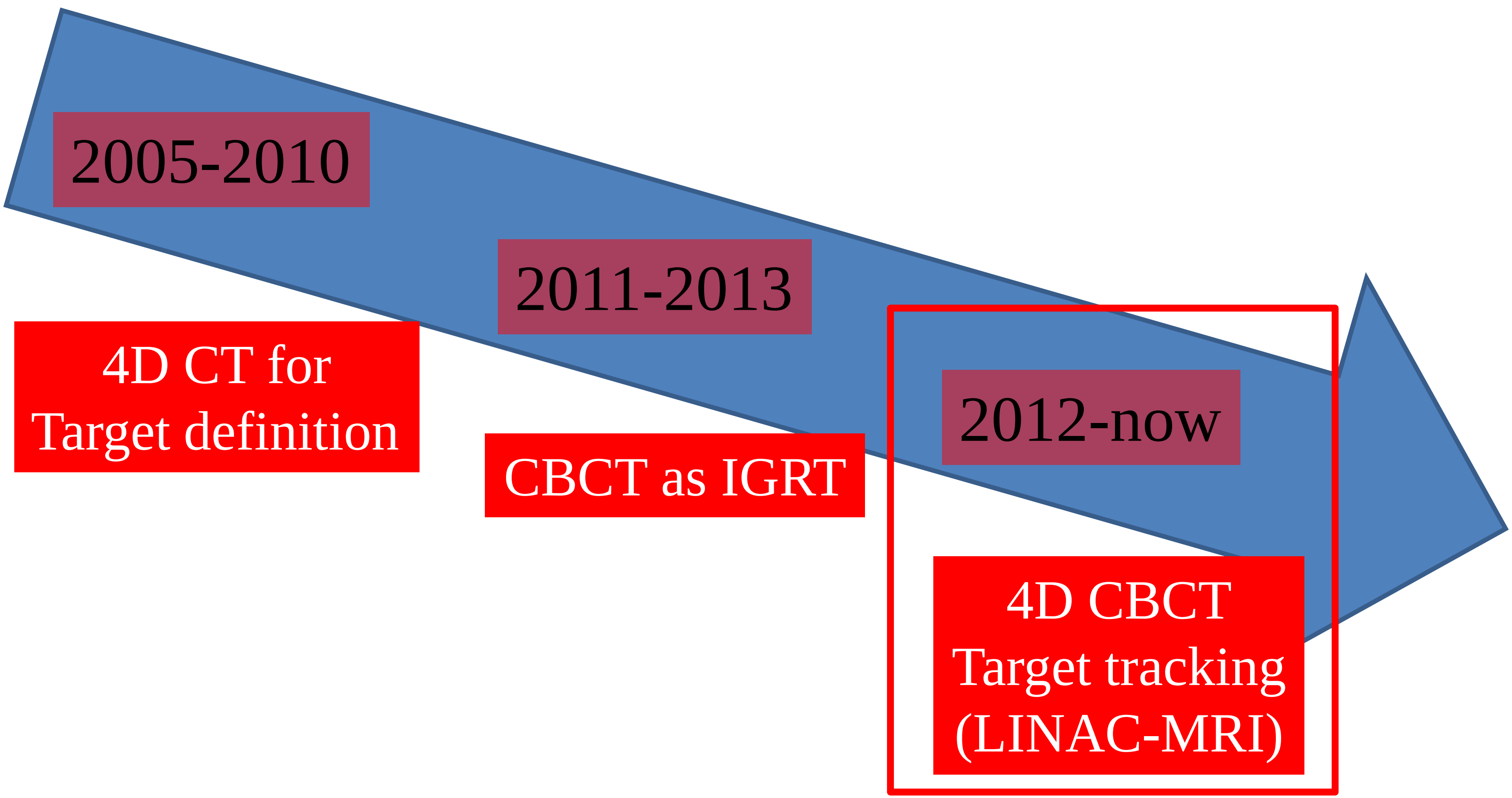
4D SBRT lung



Different techniques

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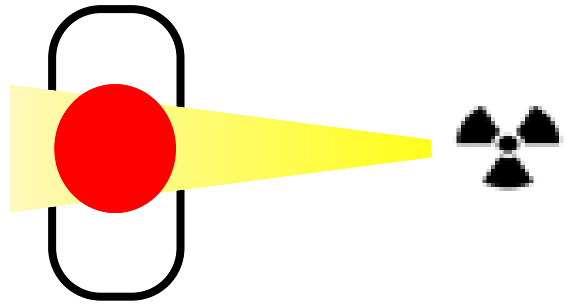
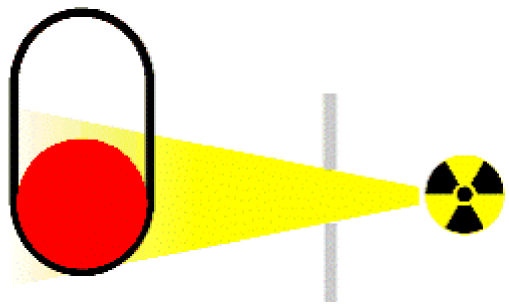
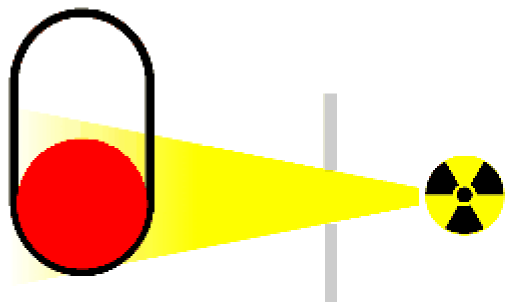
TRACKING



BREATH-HOLD

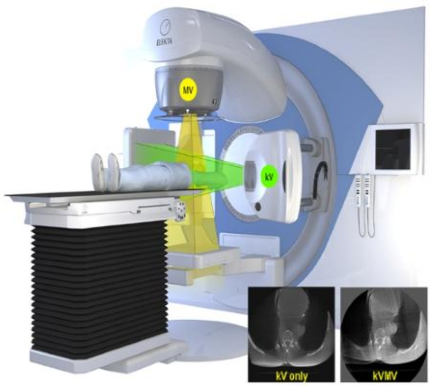


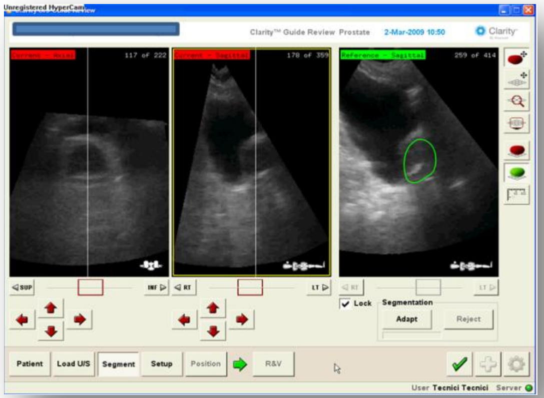
GATING



Real-time Tracking of tumor

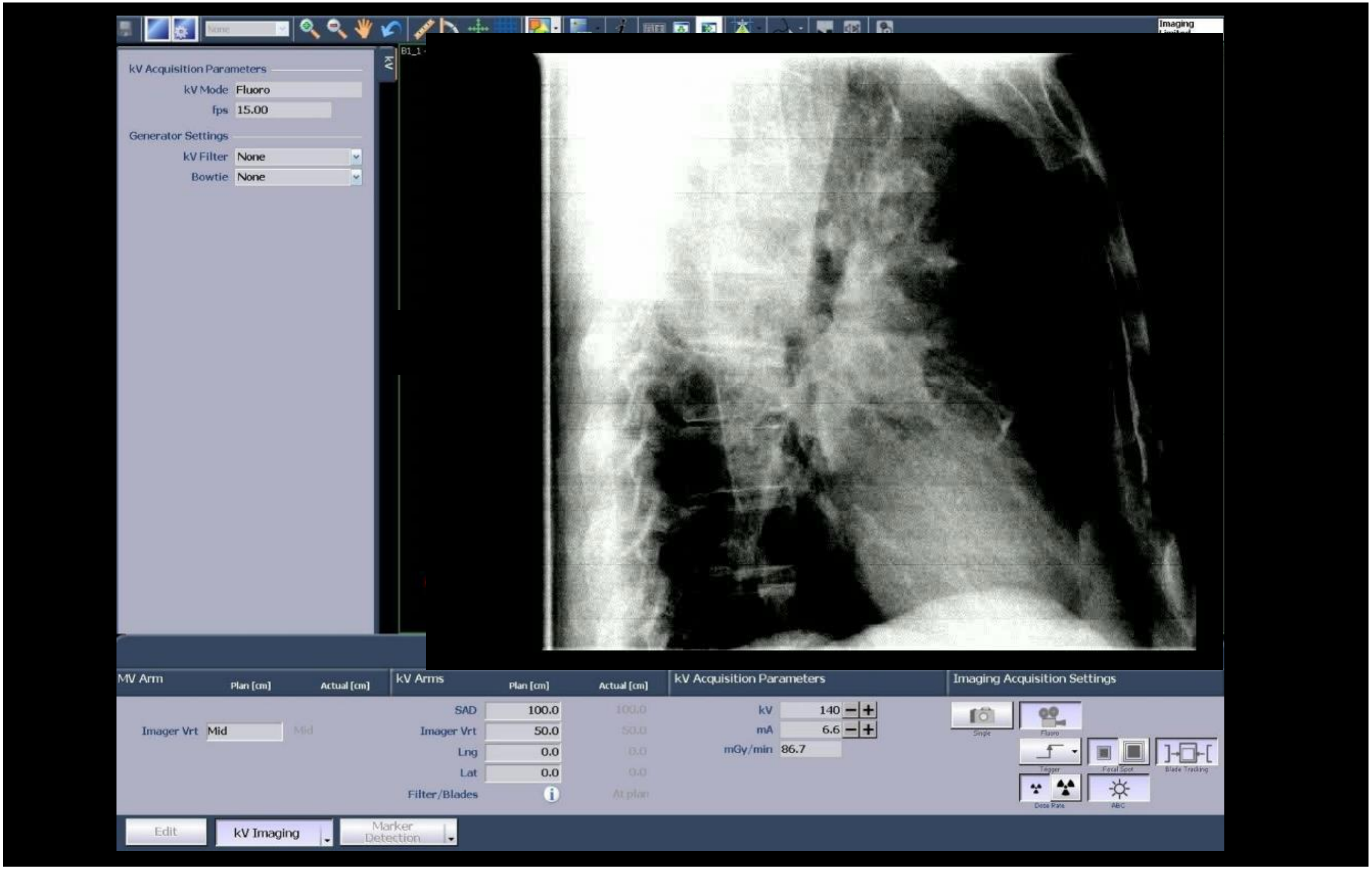
Calypso®





Clarity®

Online Fluoroscopy



Gating acquisition system

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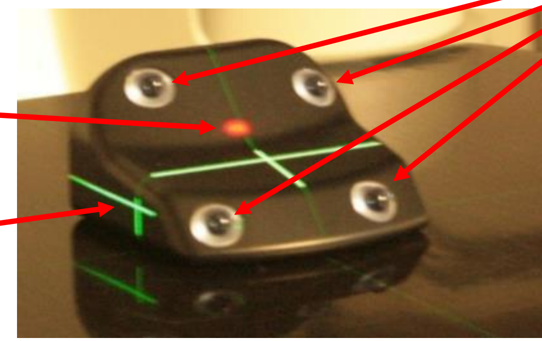
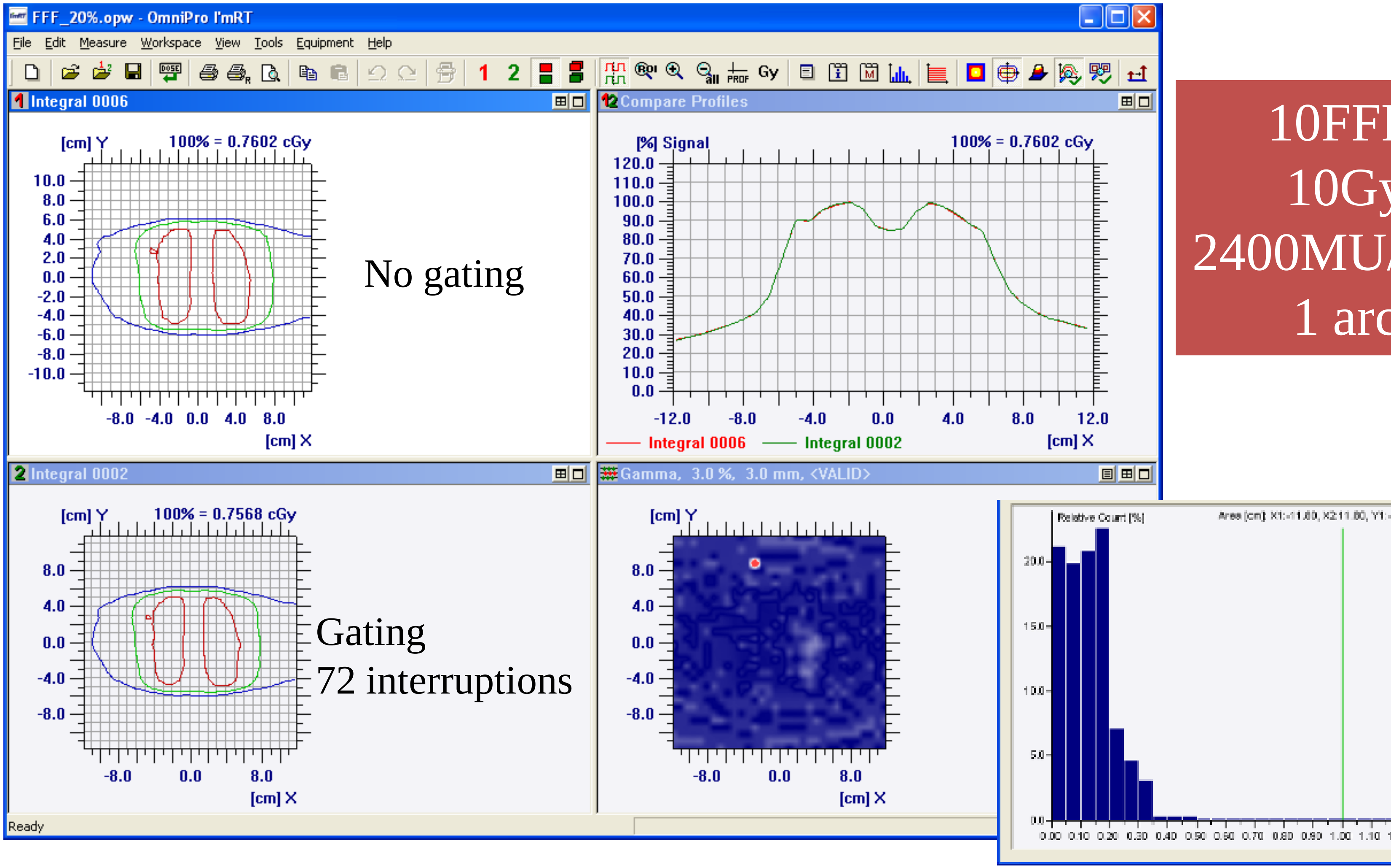
- Stereo View Video camera attached to room ceiling above couch
  - Track respiratory motion by measuring position of reflective markers



- Based on breathing pattern gates beam and imaging
  - Amplitude Based Gating
  - Phase Based Gating
  - Breath Hold
  - Patient Visual and Audio Couching
- Synchronised imaging 2D and fluoro during Delivery at given gate phases

Gating and 2D imaging

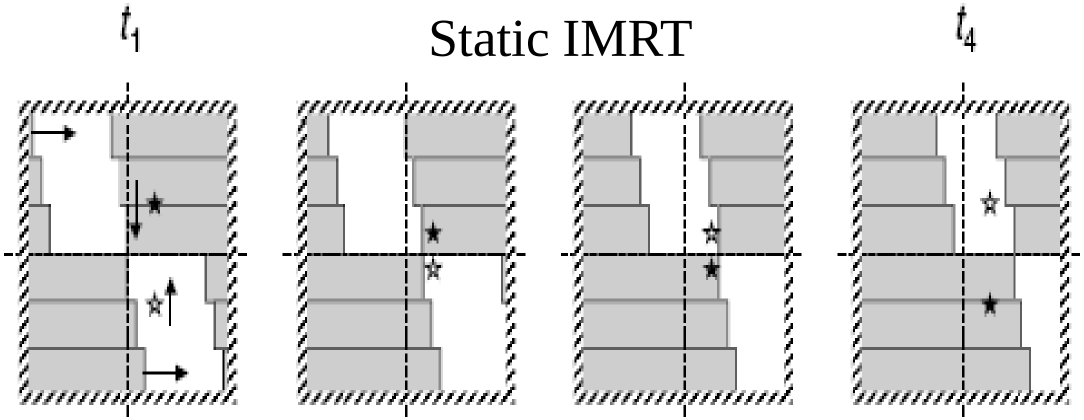
Gating during delivery: gamma evaluation



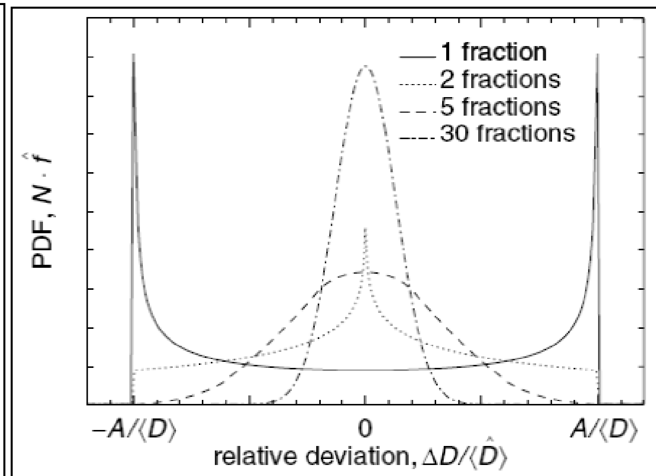
10FFF
10Gy
2400MU/min
1 arc

Interplay effect

Static IMRT



Bortfeld PMB 2002

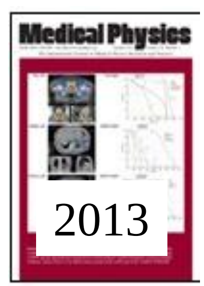


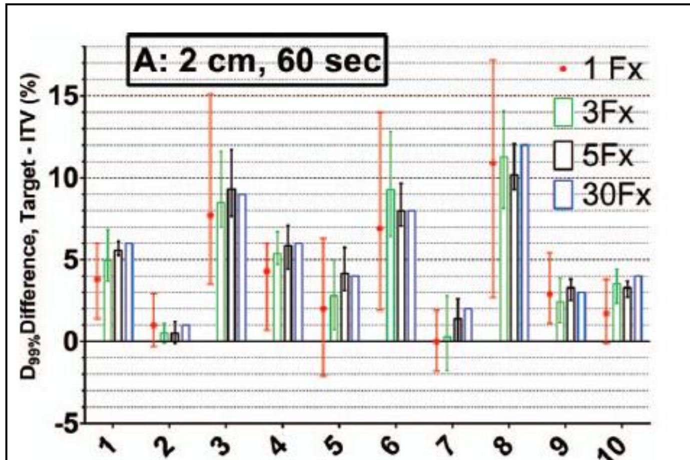
Experimentally studied dynamic dose interplay does not meaningfully affect target dose in VMAT SBRT lung treatments

Cassandra Stambaugh
Department of Physics, University of South Florida, Tampa, Florida 33612

Benjamin E. Nelms
Canis Lupus LLC, Merrimac, Wisconsin 53561

Thomas Dilling, Craig Stevens, Kujtim Latifi, Geoffrey Zhang, Eduardo Moros, and Vladimir Feygelman[a)]
Department of Radiation Oncology, Moffitt Cancer Center, Tampa, Florida 33612





Gating and SBRT

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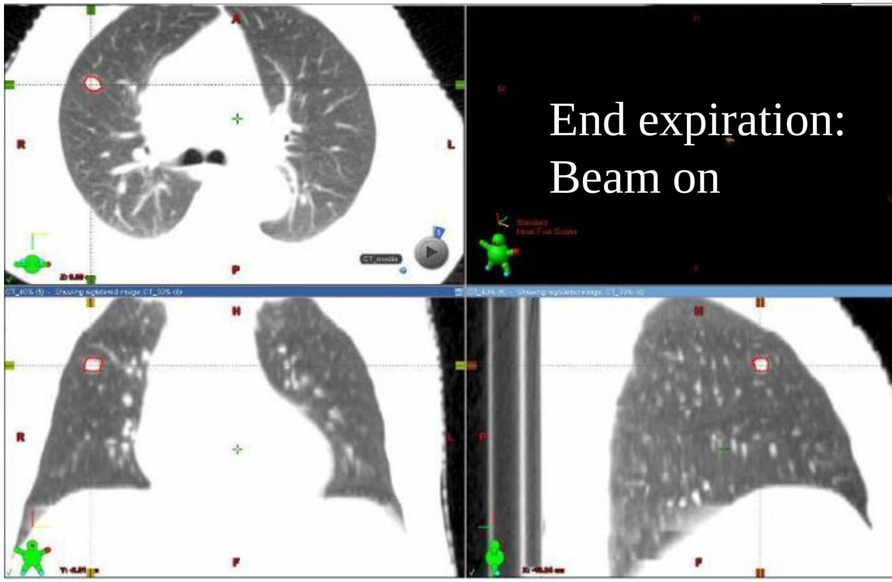
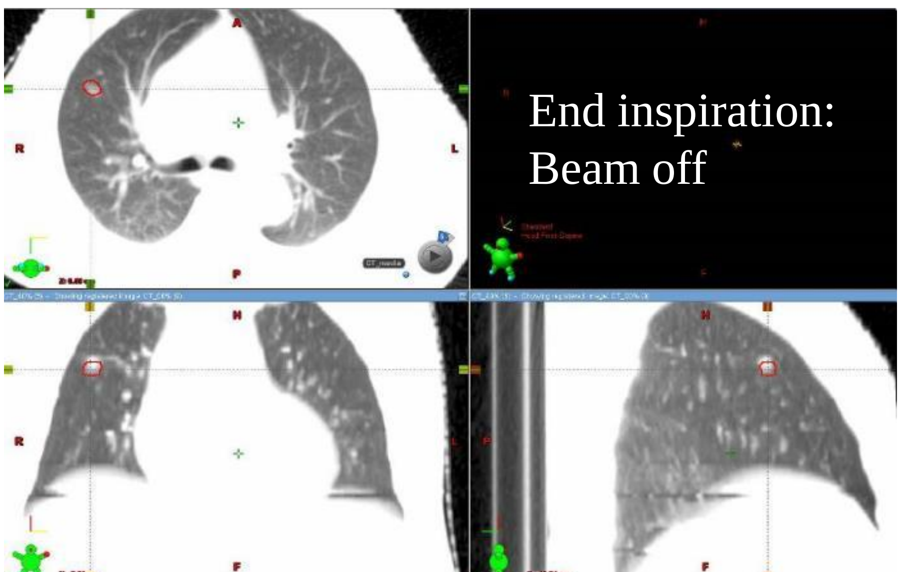
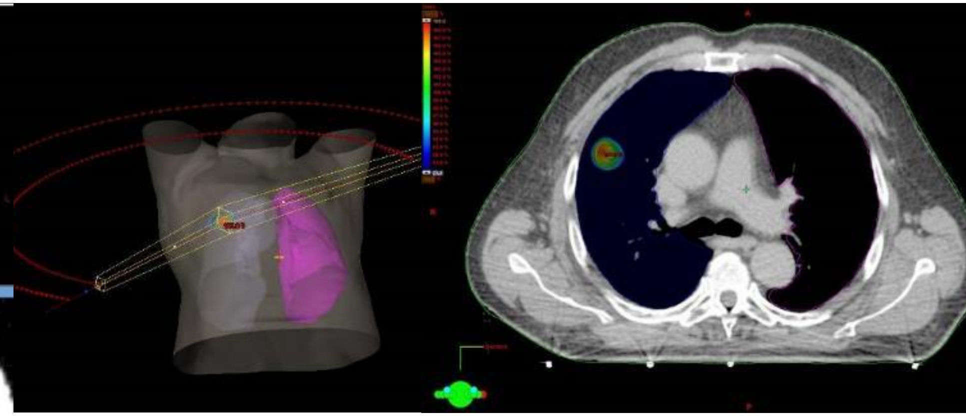
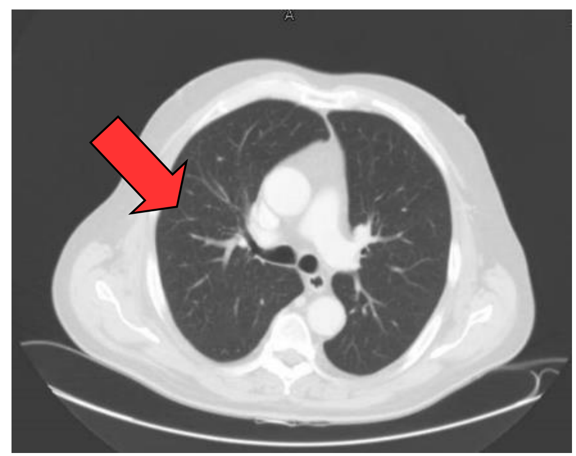




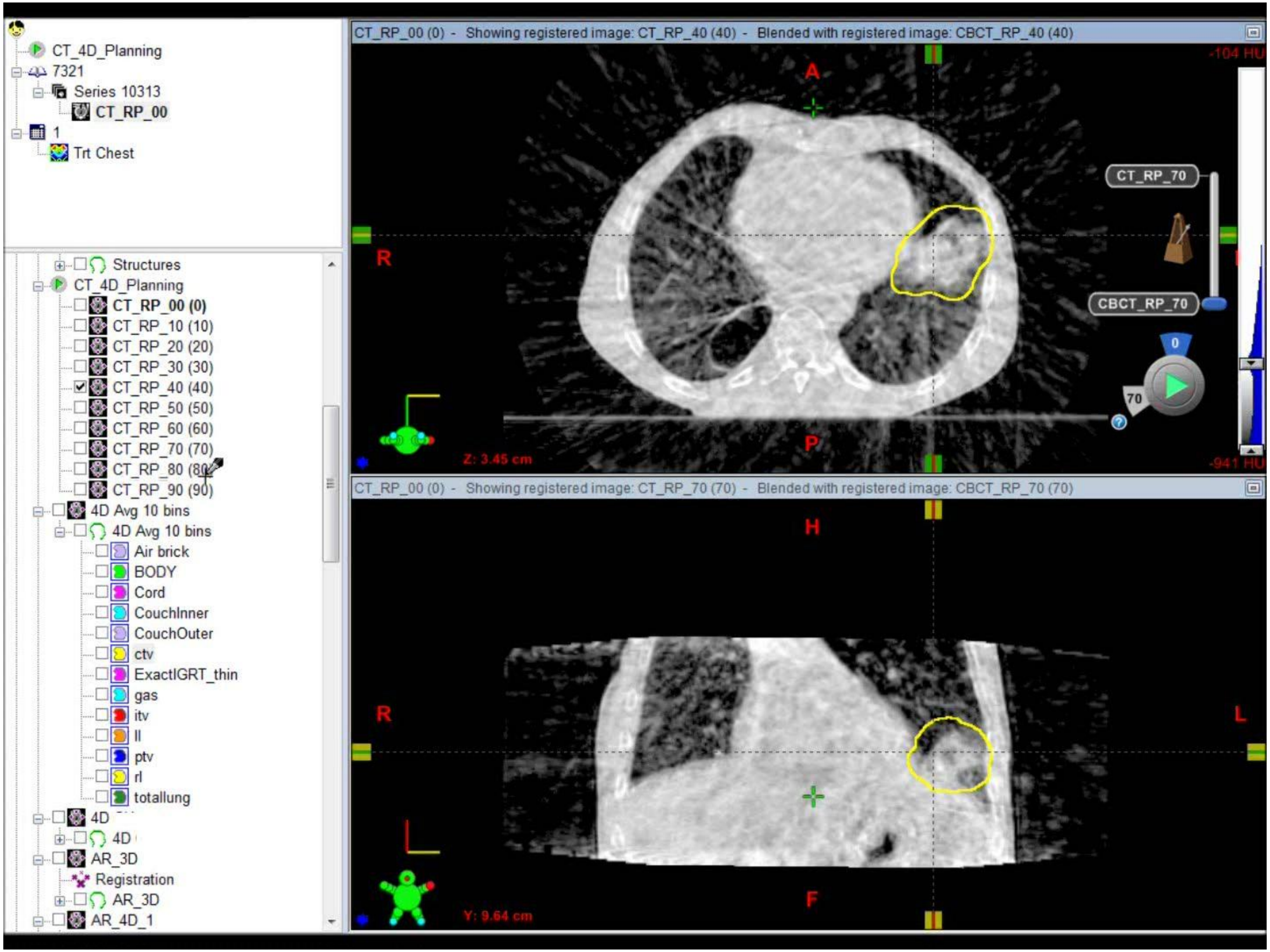


NSCLC Stage I; prescription: 20Gy x 3 days
2465+2682 MU, Total BOT: 320s
Treatment phase: 50%-75%



Complete response after 2 months

4D CBCT


CT_4D_Planning
7321
Series 10313
CT_RP_00
1
Trt Chest
Structures
CT_4D_Planning
CT_RP_00 (0)
CT_RP_10 (10)
CT_RP_20 (20)
CT_RP_30 (30)
CT_RP_40 (40)
CT_RP_50 (50)
CT_RP_60 (60)
CT_RP_70 (70)
CT_RP_80 (80)
CT_RP_90 (90)
4D Avg 10 bins
4D Avg 10 bins
Air brick
BODY
Cord
CouchInner
CouchOuter
ctv
ExactIGRT_thin
gas
itv
ll
ptv
rl
totallung
4D
4D
AR_3D
Registration
AR_3D
AR_4D_1
CT_RP_00 (0) - Showing registered image: CT_RP_40 (40) - Blended with registered image: CBCT_RP_40 (40)
-104 HU
A
R
P
CT_RP_70
CBCT_RP_70
0
70
Z: 3.45 cm
-941 HU
CT_RP_00 (0) - Showing registered image: CT_RP_70 (70) - Blended with registered image: CBCT_RP_70 (70)
H
R
L
F
Y: 9.64 cm

4D CBCT

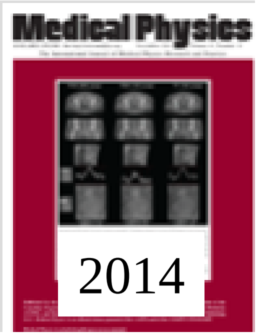
- Analyze tumor motion
- Verify tumor size

MLC tracking

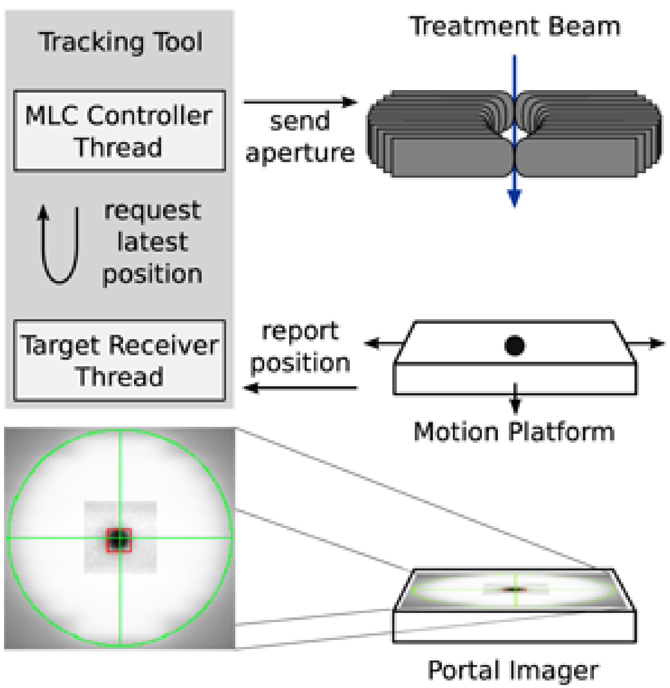
HUMANITAS CANCER CENTER

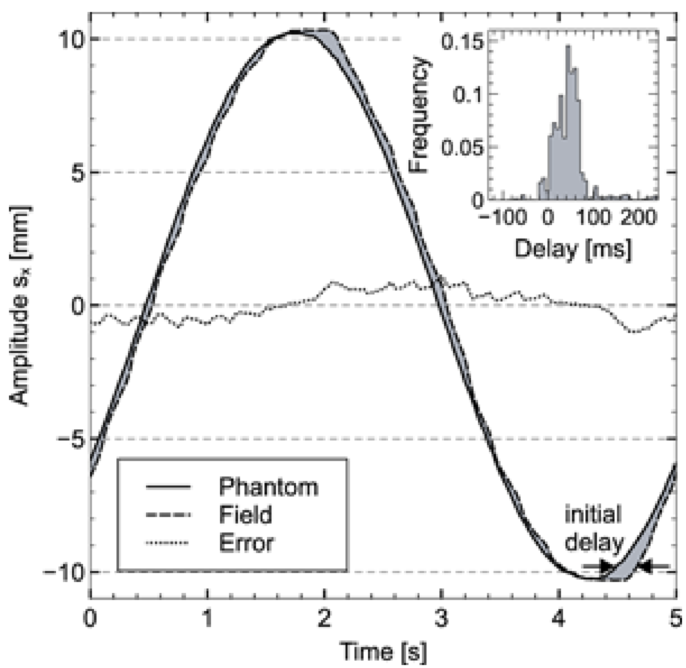
Dynamic tumor tracking using the Elekta Agility MLC

Martin F. Fast, Simeon Nill, James L. Bedford, Uwe Oelfke



The authors have developed a new control software which interfaces to the Agility MLC to dynamically program the movement of individual leaves, the dynamic leaf guides (DLGs), and the Y collimators ("jaws") based on the actual target trajectory. A motion platform was used to perform dynamic tracking experiments with sinusoidal trajectories. The actual target positions reported by the motion platform at 20, 30, or 40 Hz were used as shift vectors for the MLC in beams-eye-view. The *system latency* of the MLC (i.e., the average latency comprising *target device reporting latencies* and *MLC adjustment latency*) and the geometric tracking accuracy were extracted from a sequence of MV portal images acquired during irradiation for the following treatment scenarios: leaf-only motion, jaw + leaf motion, and DLG + leaf motion.

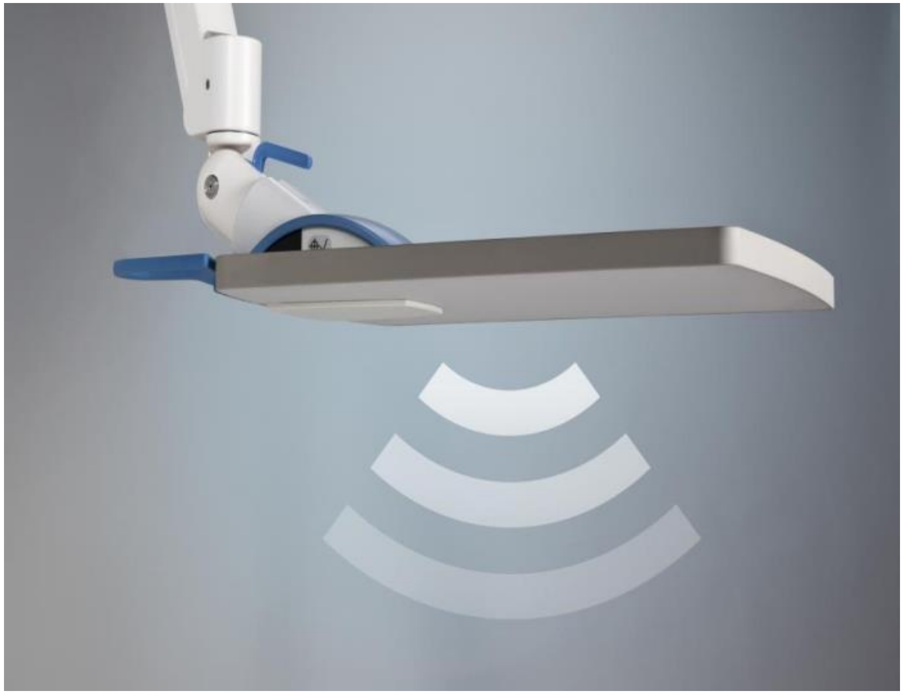




Calypso

HUMANITAS CANCER CENTER

Mixed RadioFrequency/InfraRed localization/tracking system Transponder based

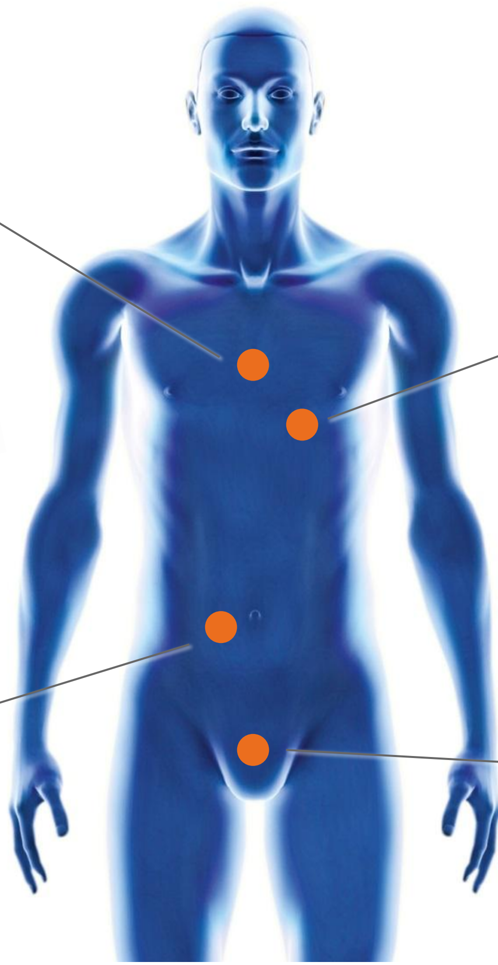


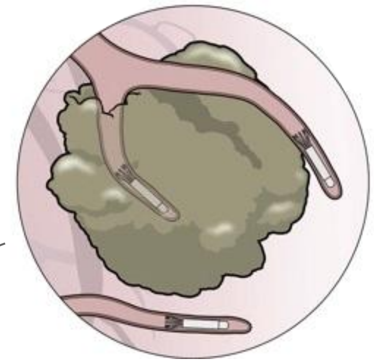
Calypso Real Time Tracking

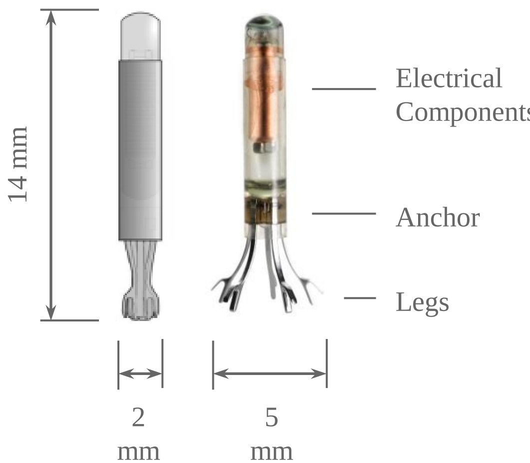
HUMANITAS CANCER CENTER

Anchored Beacon® for Lung SABR

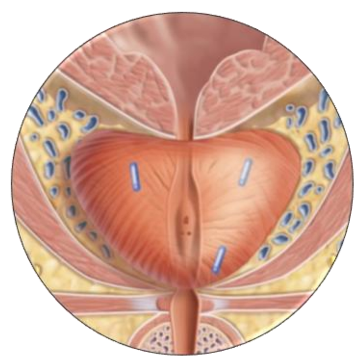
Surface Beacon







Soft Tissue Beacon

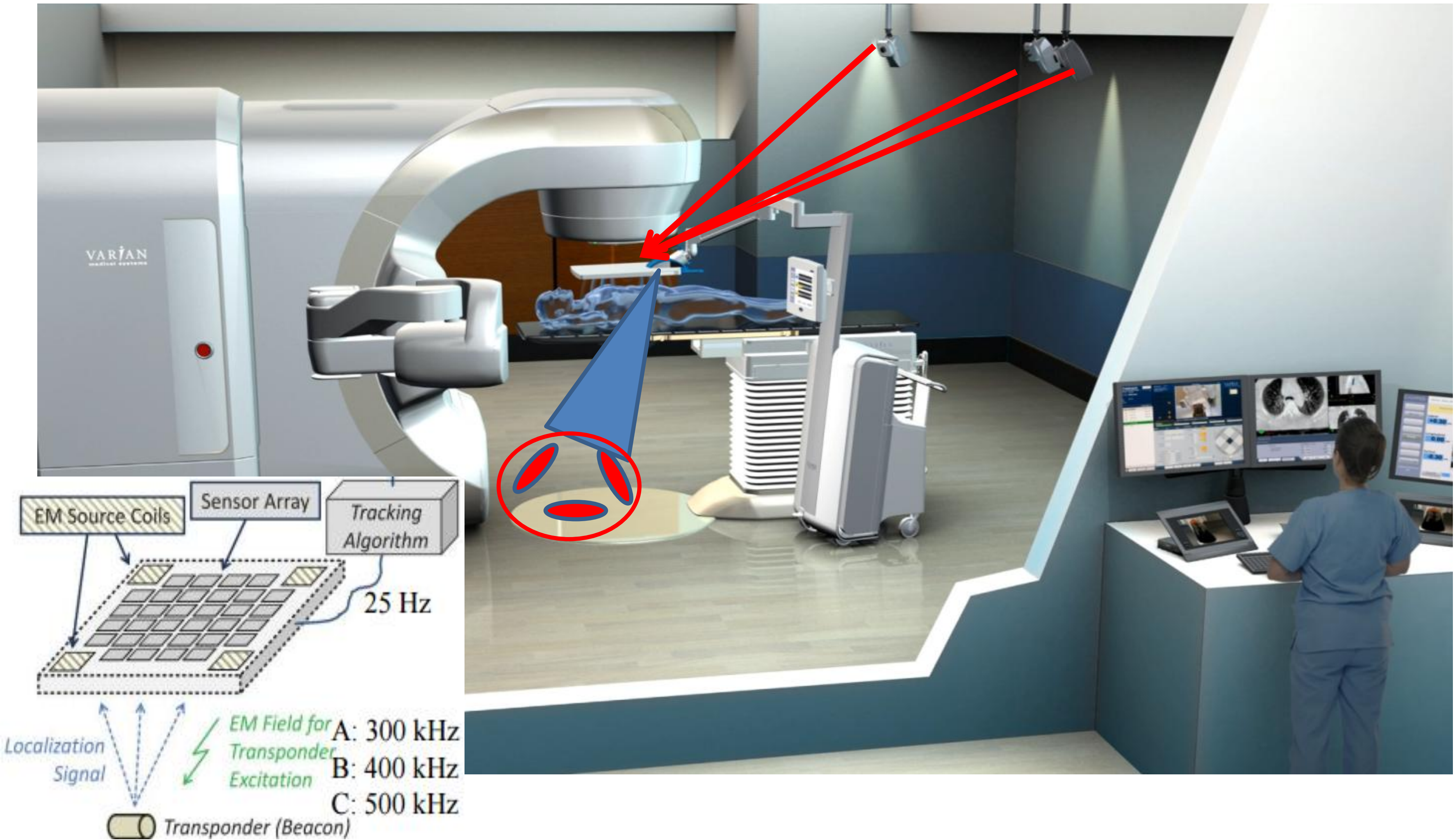


Beacon for Prostate SABR

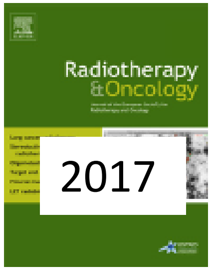
Calypso

HUMANITAS CANCER CENTER

Mixed RadioFrequency/InfraRed localization/tracking system Transponder based



Calypso: Lung case with MLC tracking

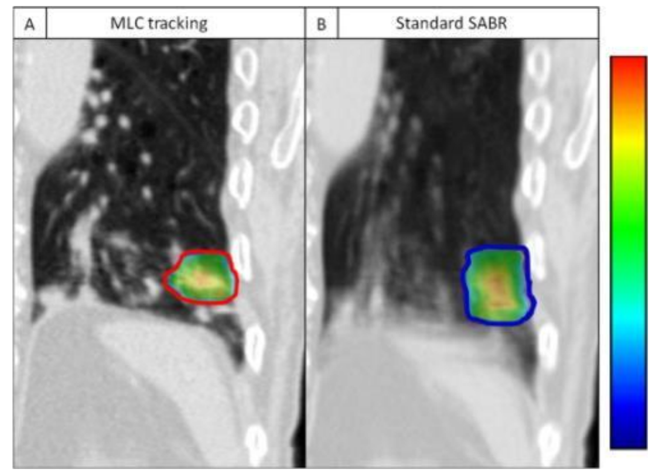


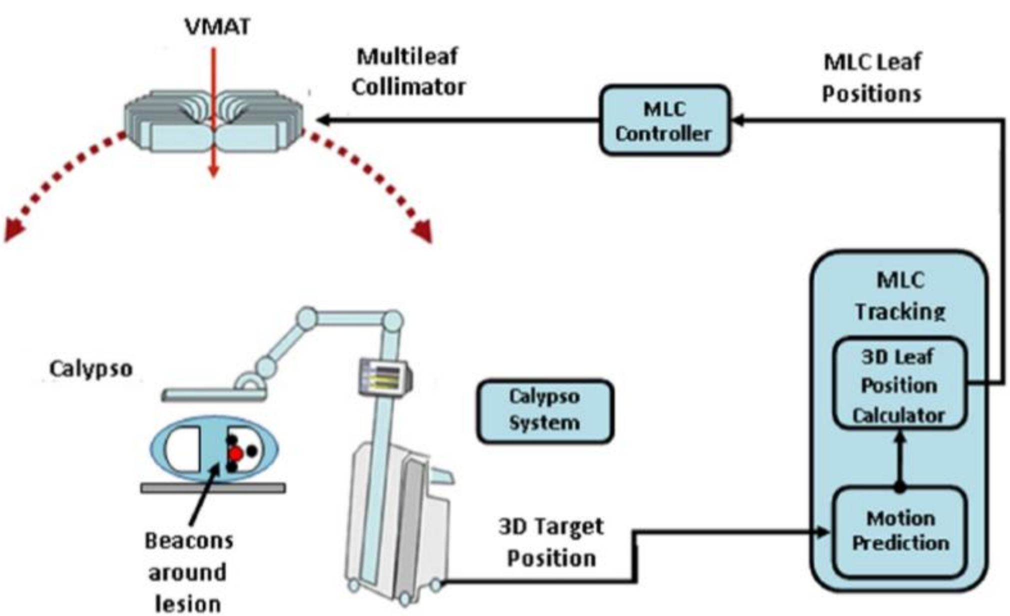
First in man

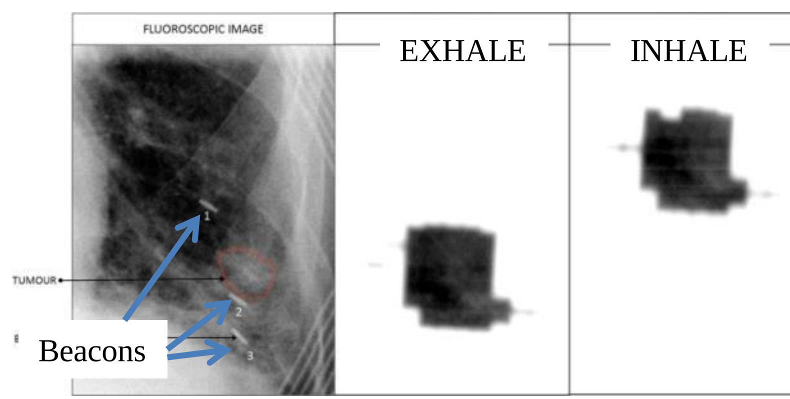
The first patient treatment of electromagnetic-guided real time adaptive radiotherapy using MLC tracking for lung SABR

Jeremy T. Booth [a,b,*], Vincent Caillet [a,b], Nicholas Hardcastle [a,c], Ricky O'Brien [b], Kathryn Szymura [a], Charlene Crasta [a], Benjamin Harris [a], Carol Haddad [a], Thomas Eade [a], Paul J. Keall [b]

[a] *Northern Sydney Cancer Centre, Level 1 Royal North Shore Hospital;* [b] *University of Sydney, Schools of Physics or Medicine, Sydney; and* [c] *Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia*

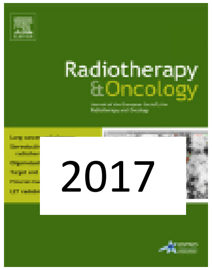






Calypso: Lung case with MLC tracking

HUMANITAS CANCER CENTER



First in man

The first patient treatment of electromagnetic-guided real time adaptive radiotherapy using MLC tracking for lung SABR

CrossMark

Jeremy T. Booth [a,b,*], Vincent Caillet [a,b], Nicholas Hardcastle [a,c], Ricky O'Brien [b], Kathryn Szymura [a], Charlene Crasta [a], Benjamin Harris [a], Carol Haddad [a], Thomas Eade [a], Paul J. Keall [b]

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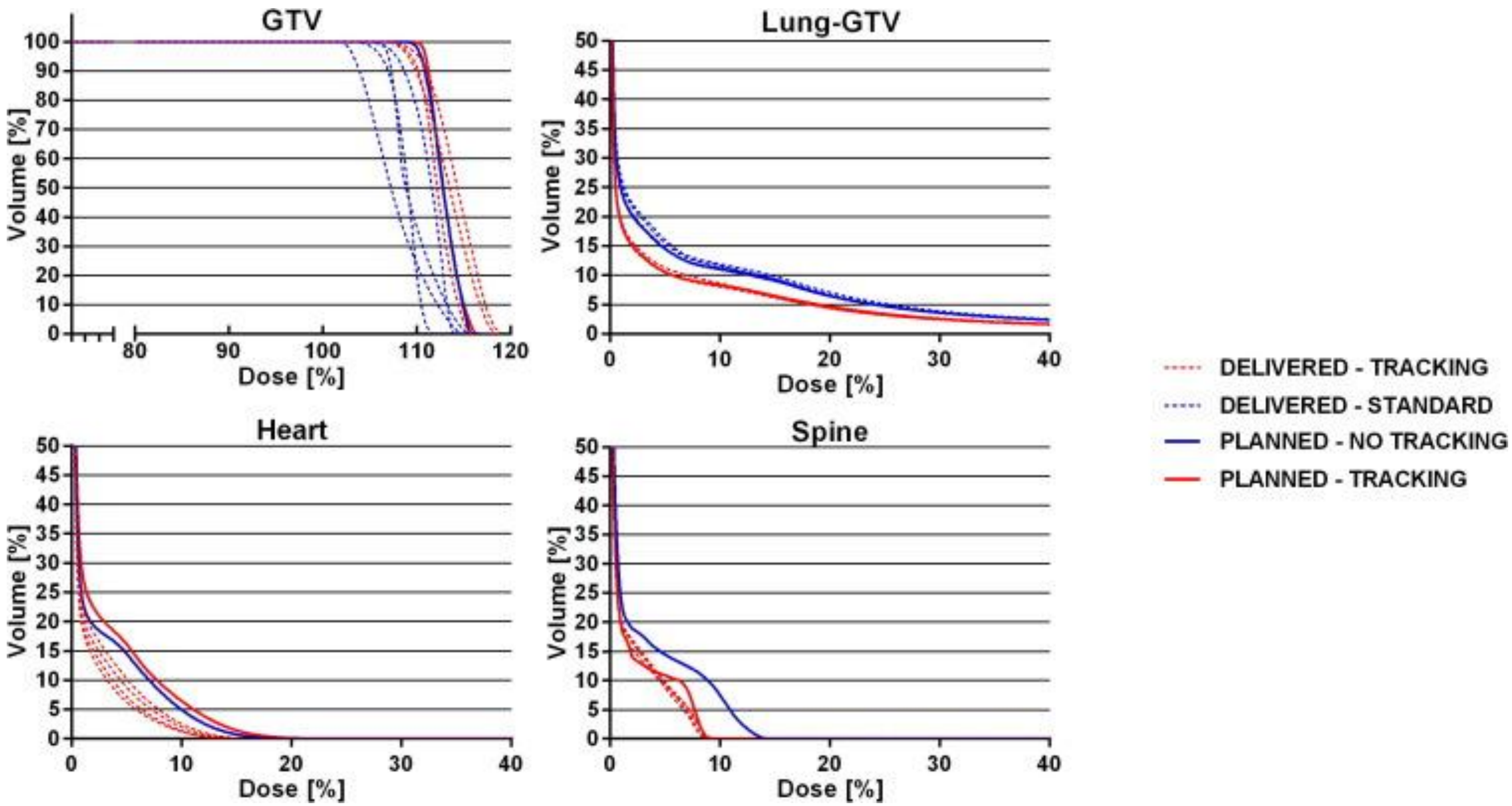


Index

HUMANITAS CANCER CENTER

Lung mobility

4D CT for target definition

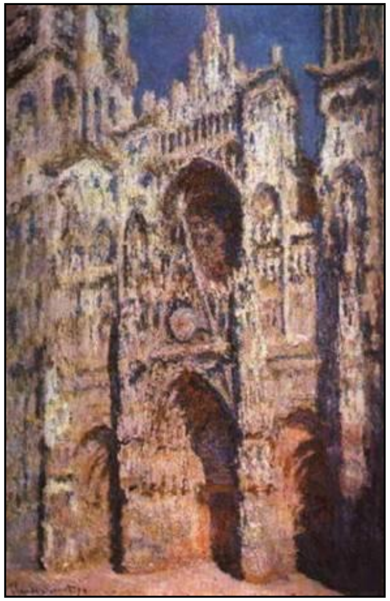
IGRT

Tumor and MLC tracking

SBRT vs standard RT in lung

Not only breathing motion

Take home messages

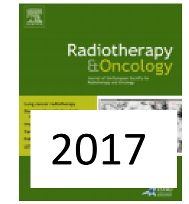


Monet –Rouen cathedral, 1893/94

SBRT vs conventional fractionation

HUMANITAS CANCER CENTER

Phase III randomised trial



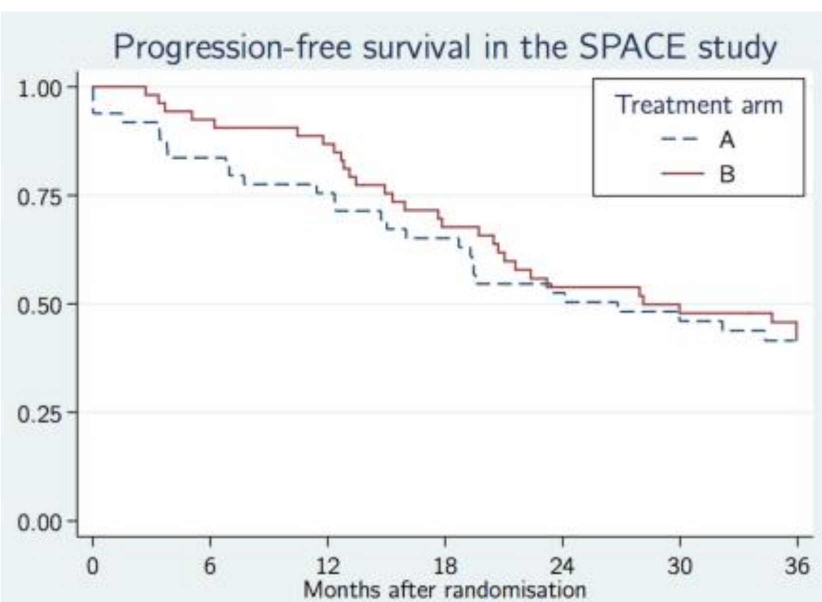
SPACE – A randomized study of SBRT vs conventional fractionated radiotherapy in medically inoperable stage I NSCLC

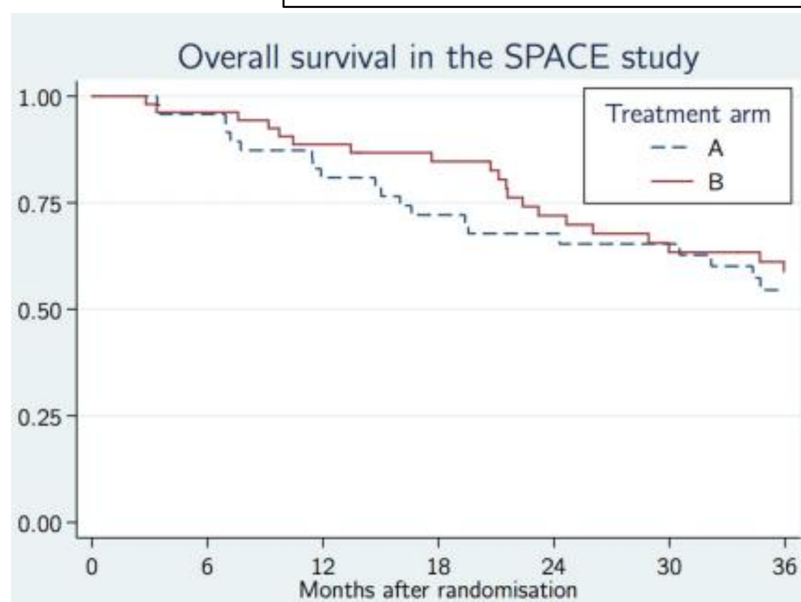
Jan Nyman [a,*], Andreas Hallqvist [a], Jo-Åsmund Lund [b], Odd-Terje Brustugun [c], Bengt Bergman [a], Per Bergström [d], Signe Friesland [e], Rolf Lewensohn [e], Erik Holmberg [a], Ingmar Lax [e]

CT was performed before the first treatment to verify tumor reproducibility with predefined tolerance limits. CBCT (cone beam CT) and 4DCT was allowed but only available at a few sites. A heterogeneous dose distribution within the PTV was used. The prescribed

SBRT (3 fractions)
Tot: 45Gy (perifery) 66Gy (center)

Standard (35 fractions):
Tot: 70Gy





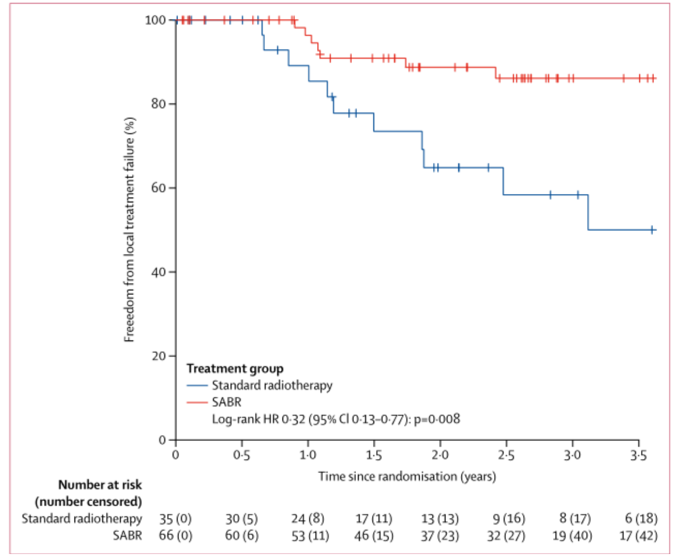
SBRT vs conventional fractionation

HUMANITAS CANCER CENTER

THE LANCET Oncology 2019

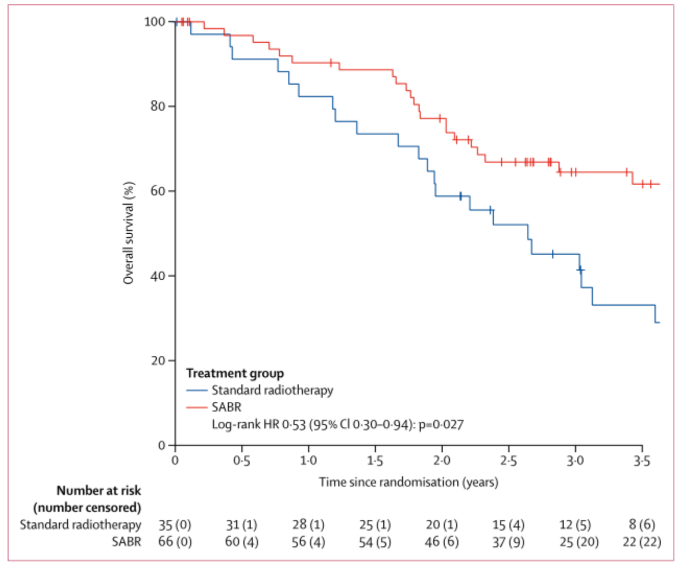
Stereotactic ablative radiotherapy versus standard radiotherapy in stage 1 non-small-cell lung cancer (TROG 09.02 CHISEL): a phase 3, open-label, randomised controlled trial

David Ball, G Tao Mai, Shalini Vinod, Scott Babington, Jeremy Ruben, Tomas Kron, Brent Chesson, Alan Herschtal, Marijana Vanevski, Angela Rezo, Christine Elder, Marketa Skala, Andrew Wirth, Greg Wheeler, Adeline Lim, Mark Shaw, Penelope Schofield, Louis Irving, Benjamin Solomon, on behalf of the TROG 09.02 CHISEL investigators



Added value of this study

To our knowledge, this was the first randomised trial to compare stereotactic ablative body radiotherapy (SABR) with standard radiotherapy in patients who had pathologically proven non-small cell lung cancer at stage T1–T2aN0M0, as determined by ^{18}F-fluorodeoxyglucose (FDG)-PET scanning. This was also, to our knowledge, the first trial in which all radiotherapy plans took into account tumour motion, either with 4D CT (for patients randomly assigned to SABR) or FDG-PET scanning (for patients randomly assigned to standard radiotherapy).



Index

HUMANITAS CANCER CENTER

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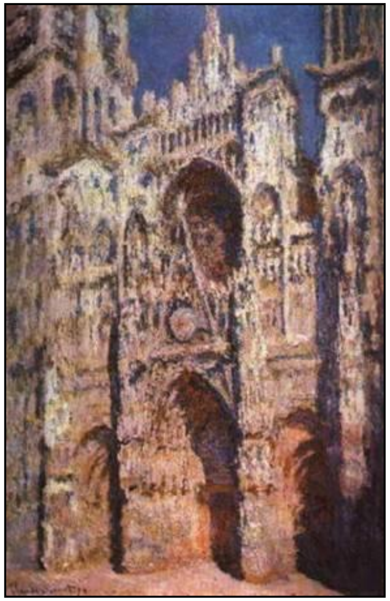
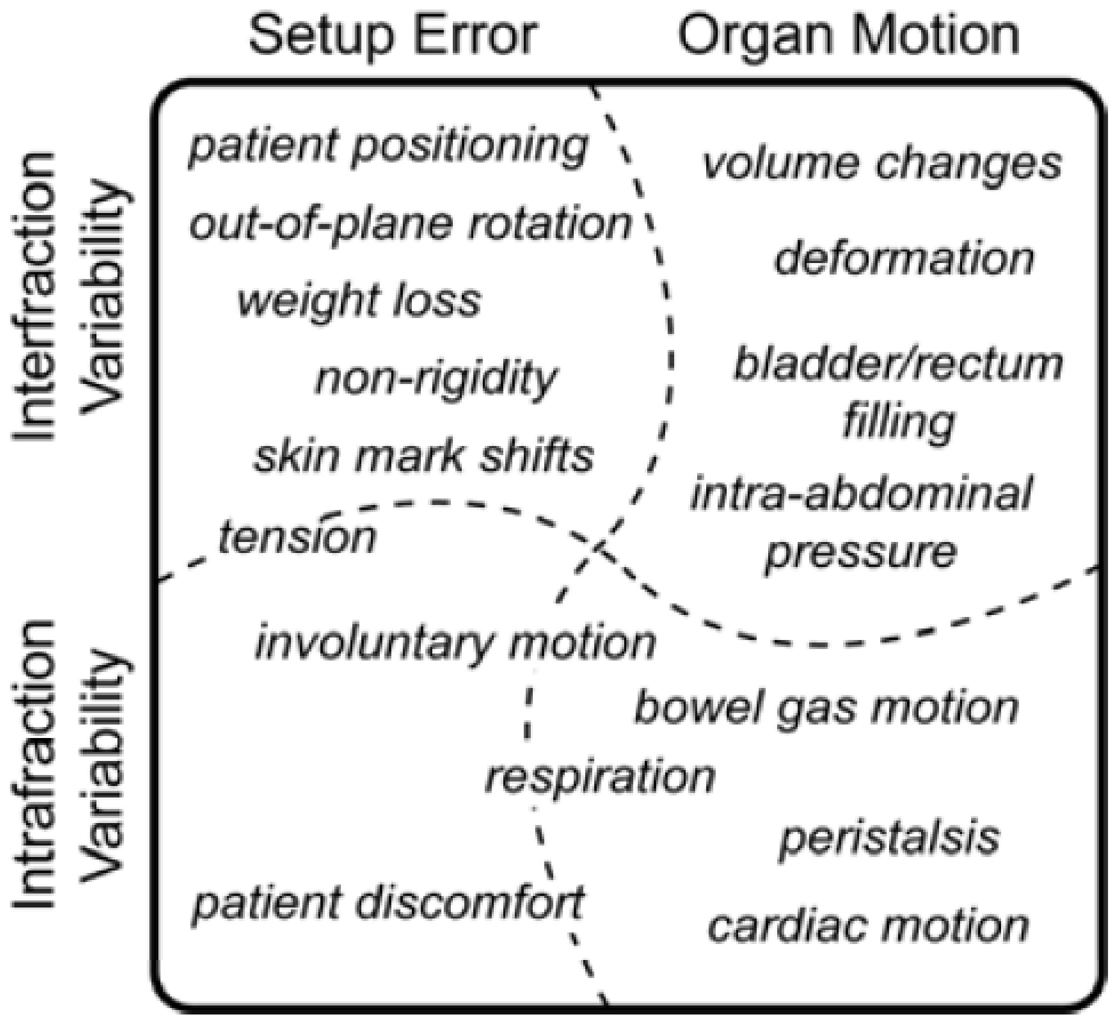


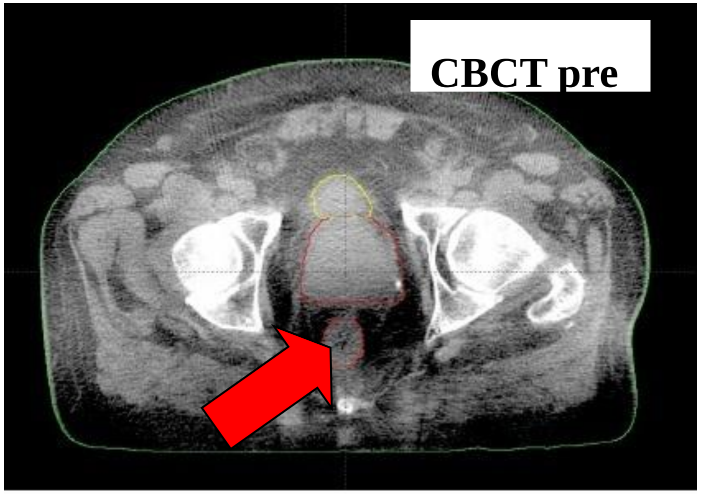
Monet –Rouen cathedral, 1893/94

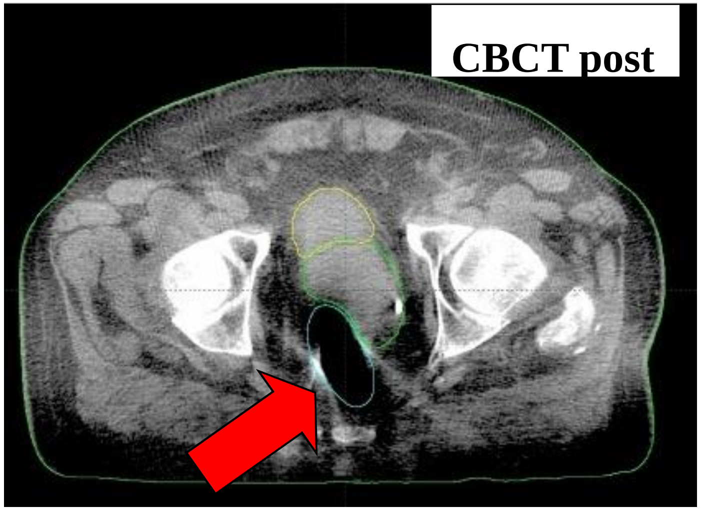
Target uncertaities in Radiotherapy

HUMANITAS CANCER CENTER



Question of motion



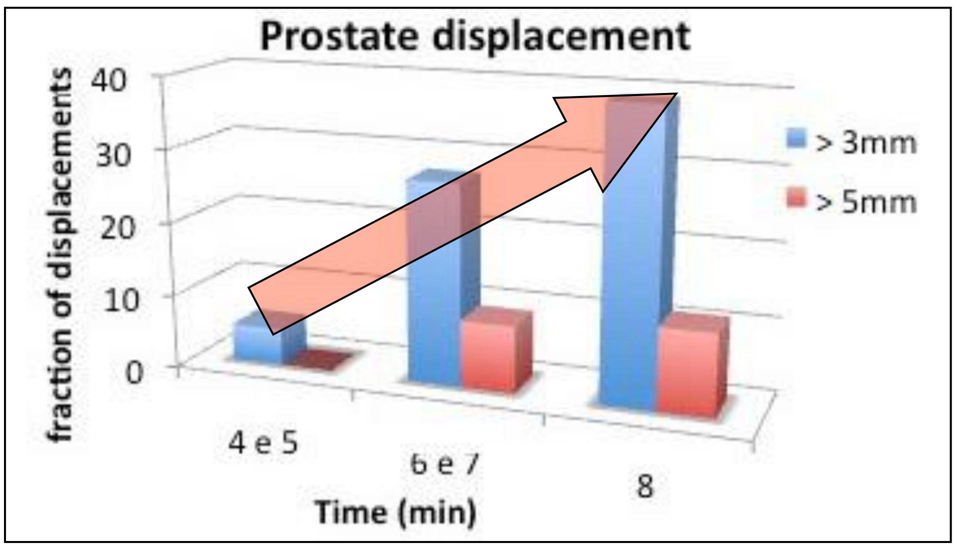


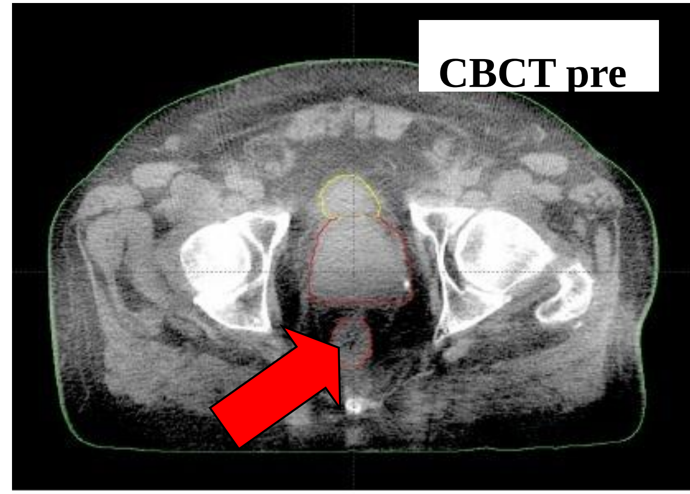
Prostate Intra-Motion

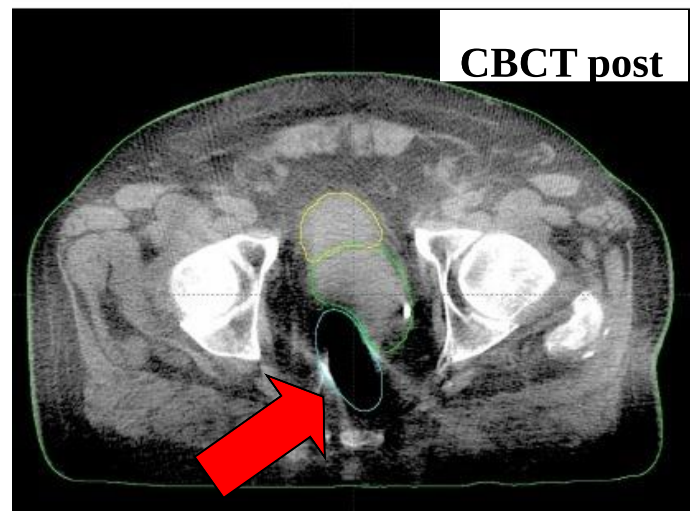
JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 12, NUMBER 1, WINTER 2011

Cone beam CT pre- and post-daily treatment for assessing geometrical and dosimetric intrafraction variability during radiotherapy of prostate cancer

Giacomo Reggiori,[1] Pietro Mancosu,[1a] Angelo Tozzi,[1] Marie C Cantone,[2] Simona Castiglioni,[1] Paola Lattuada,[1] Francesca Lobefalo,[1] Luca Cozzi,[3] Antonella Fogliata,[3] Piera Navarria,[1] Marta Scorsetti[1]
Radiation Oncology Dept.,[1] IRCCS Istituto Clinico Humanitas, Milano (Rozzano), Italy; Physics Dept.,[2] Università degli studi di Milano, Milano, Italy; Medical Physics Unit,[3] Oncology Institute of Southern Switzerland, Bellinzona, Switzerland
pietro.mancosu@humanitas.it

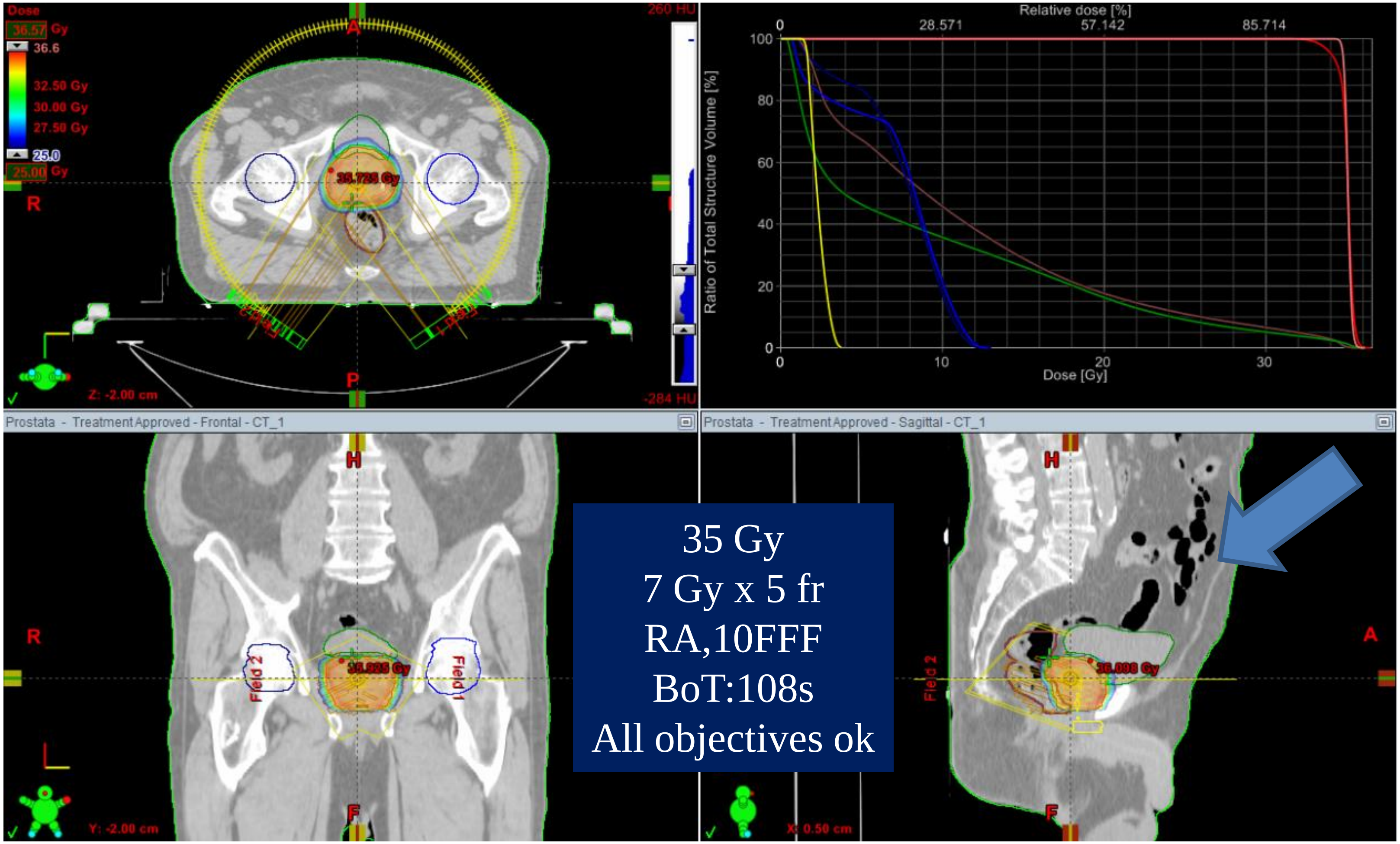






Difficult case@Humanitas

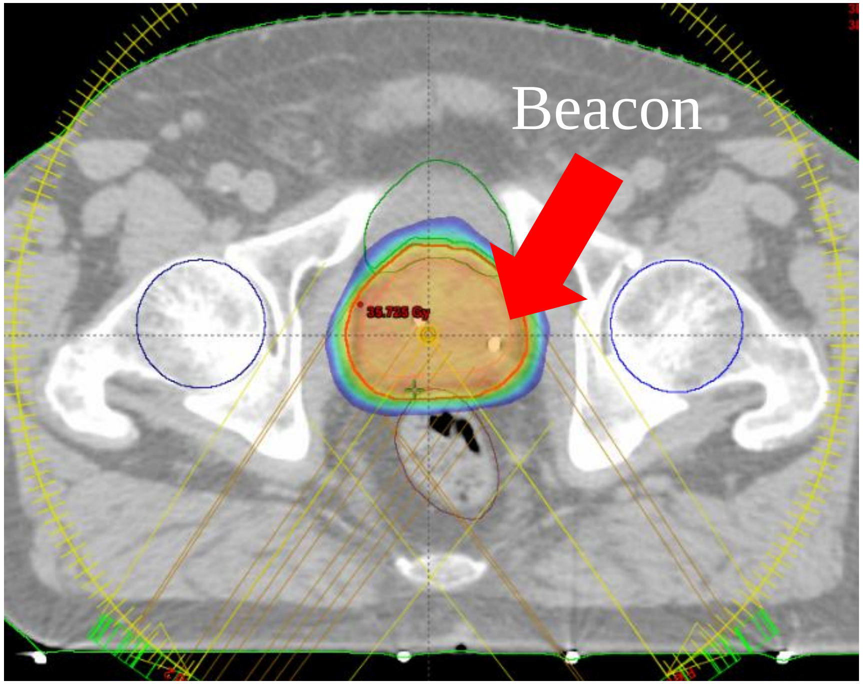
HUMANITAS CANCER CENTER



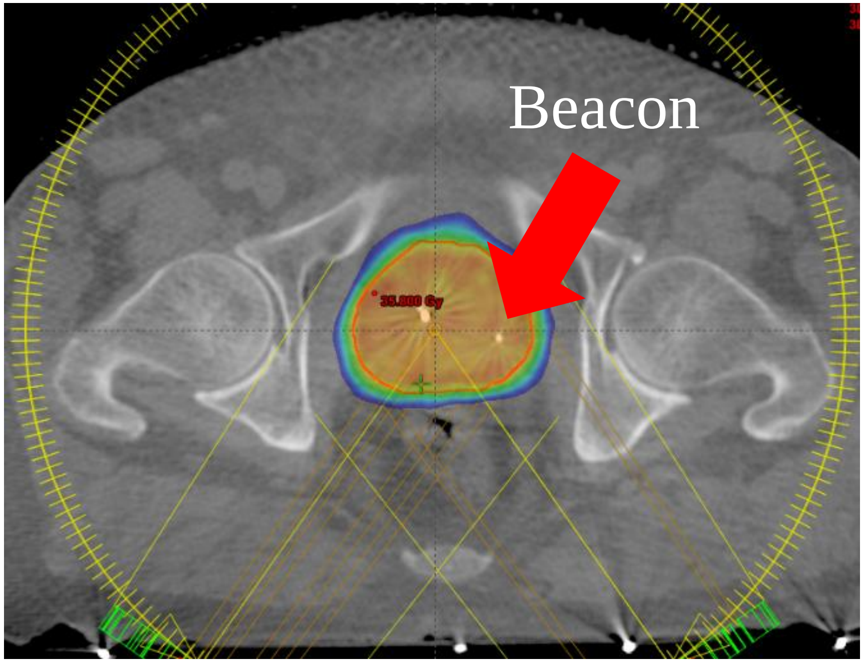
35 Gy
7 Gy x 5 fr
RA,10FFF
BoT:108s
All objectives ok

Prostate with Calypso

HUMANITAS CANCER CENTER



Simulation CT



CBCT 1

Calypso: Patient Data

HUMANITAS
CANCER CENTER

CALYPSO — Patient Session Report
Summary

Localization Summary

Isocenter Localization	Lat (Left+)	Long (Sup+)	Vert (Ant+)
Shift from Initial Setup (cm):	0.00	-0.02	-0.01
Confirmed Isocenter Offset (cm):	-0.22	0.07	-0.32
Time:	09:37:50 AM		

Intertransponder Distances	Planned	Measured
A to B (cm):	3.18	3.13
B to C (cm):	0.59	0.48
C to A (cm):	2.85	2.85

Geometry Checks	Limit	Measured
Geometric Residual (cm):	0.40	0.05
Rotation - Pitch (°):	30	0
Rotation - Roll (°):	30	2
Rotation - Yaw (°):	30	0

Session Overrides

None

Tracking Mode: Centroid

Tracking Summary

Total Tracking Time (hh:mm:ss): 0:15:05
Tracking Time while radiation detected: 0:01:40

Summary of Target Excursions Outside of Tracking Limits

	Tracking	Total Tracking Time			Tracking while Radiation Detected		
Direction	Limit	Time	Percent	Max Excur	Time	Percent	Max Excur
Left	0.30 cm	0 sec	0%	0.10 cm	0 sec	0%	0.01 cm
Right	0.30 cm	0 sec	0%	0.28 cm	0 sec	0%	0.15 cm
Superior	0.30 cm	0 sec	0%	0.20 cm	0 sec	0%	0.11 cm
Inferior	0.30 cm	74 sec	8%	0.49 cm	0 sec	0%	-0.03 cm
Anterior	0.30 cm	84 sec	9%	0.75 cm	0 sec	0%	0.18 cm
Posterior	0.30 cm	198 sec	22%	0.53 cm	0 sec	0%	0.12 cm
Total		356 sec	39%		0 sec	0%	

Adaptive Couch Repositioning Request Summary

None

Couch Angles Summary

Angles: Nominal Only (0°)

Set Zero Summary

Approver	Time	ΔLat (Left+)	ΔLong (Sup+)	ΔVert (Ant+)	Lat (Left+)	Long (Sup+)	Vert (Ant+)
AdvTherapist	09:45:39 AM	-0.1 cm	-0.4 cm	0.0 cm	-0.1 cm	-0.4 cm	0.0 cm
AdvTherapist	09:48:40 AM	0.0 cm	0.0 cm	0.1 cm	-0.1 cm	-0.4 cm	0.1 cm
AdvTherapist	09:50:20 AM	0.1 cm	0.0 cm	0.0 cm	0.0 cm	-0.4 cm	0.1 cm

CALYPSO — Patient Session Report
Localization Plan

Patient Information

Patient:
Patient ID:
Patient or Plan Last Modified: Sep 30, 2014 06:19:24 PM
Institution: Istituto Clinico Humanitas
Room: EDGE

Localization Plan

Implantation Date: Sep 30, 2014
Patient Orientation: Supine
Usage Mode: Set Zero and Track
Gating: Enabled
Physician:
Dosimetrist:
Medical Physicist:
Geometric Residual Limit (cm): 0.40
Rotational Alignment Limit (°): 30.00

Transponders	X	Y	Z	Frequency
Treatment Isocenter (mm):	5.8	104.5	-617.0	
▲ A (mm):	29.2	107.9	-619.5	1
● B (mm):	1.2	95.0	-611.7	3
■ C (mm):	2.4	98.8	-616.0	2
Coordinate Reference Frame:	Varian Eclipse			

Tracking	Lat (Left+)	Long (Sup+)	Vert (Ant+)
Upper Tracking Limits (cm):	0.30	0.30	0.30
Lower Tracking Limits (cm):	-0.30	-0.30	-0.30
Max set zero offset from plan (cm):	2.0		

Plan Overrides:

Beacon transponders too close to being collinear

Transponder Frequency Association

*Selected Association ▲ 1 ● 3 ■ 2

Transponder Frequency Association Options

Status	Transponder Associations			Geom Res	Rotation	Yaw	Pitch	Roll
*Recommended	▲ 1	● 3	■ 2	0.04 cm	3°	---	---	---
Not Allowed	▲ 2	● 1	■ 3	1.35 cm	171°	---	---	---
Not Allowed	▲ 3	● 2	■ 1	1.38 cm	172°	---	---	---
Not Allowed	▲ 1	● 2	■ 3	0.24 cm	177°	---	---	---
Not Allowed	▲ 3	● 1	■ 2	1.16 cm	178°	---	---	---
Not Allowed	▲ 2	● 3	■ 1	1.55 cm	178°	---	---	---

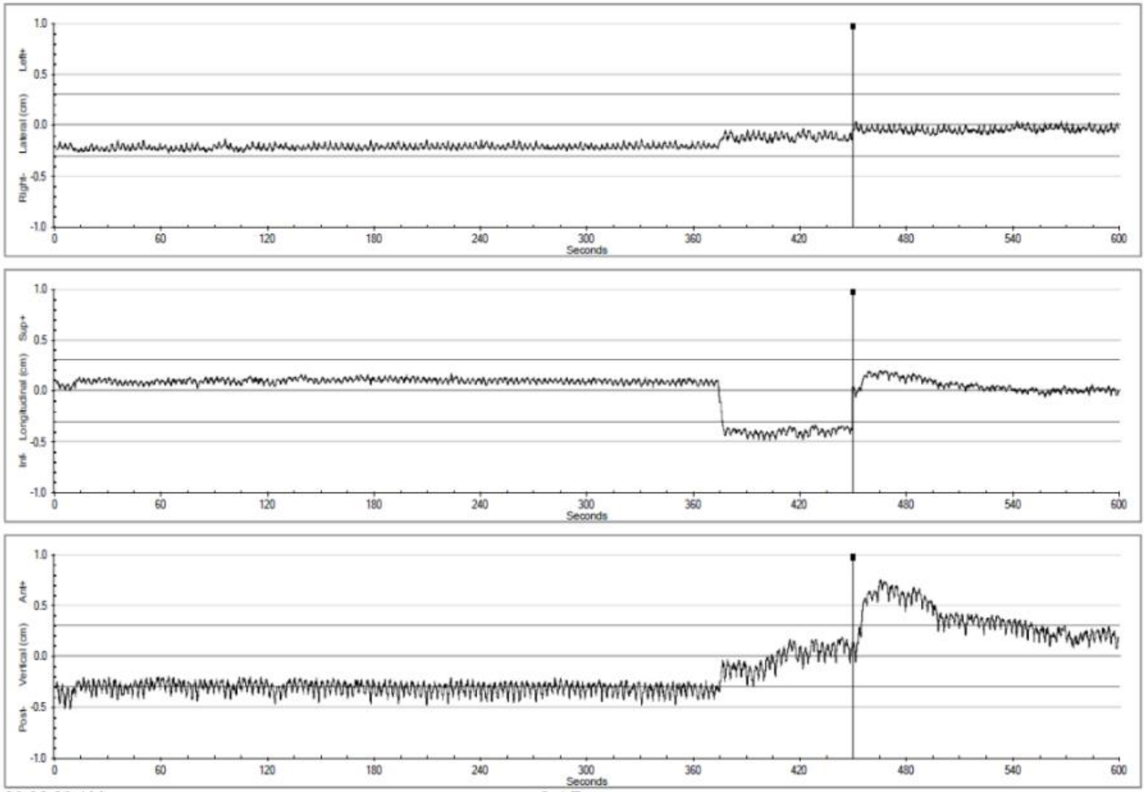
*** This association was finalized and approved by AdvTherapist on Oct 1, 2014 09:37:11 AM**

Calypso: Patient tracking

HUMANITAS CANCER CENTER

CALYPSO

Patient Session Report
Tracking

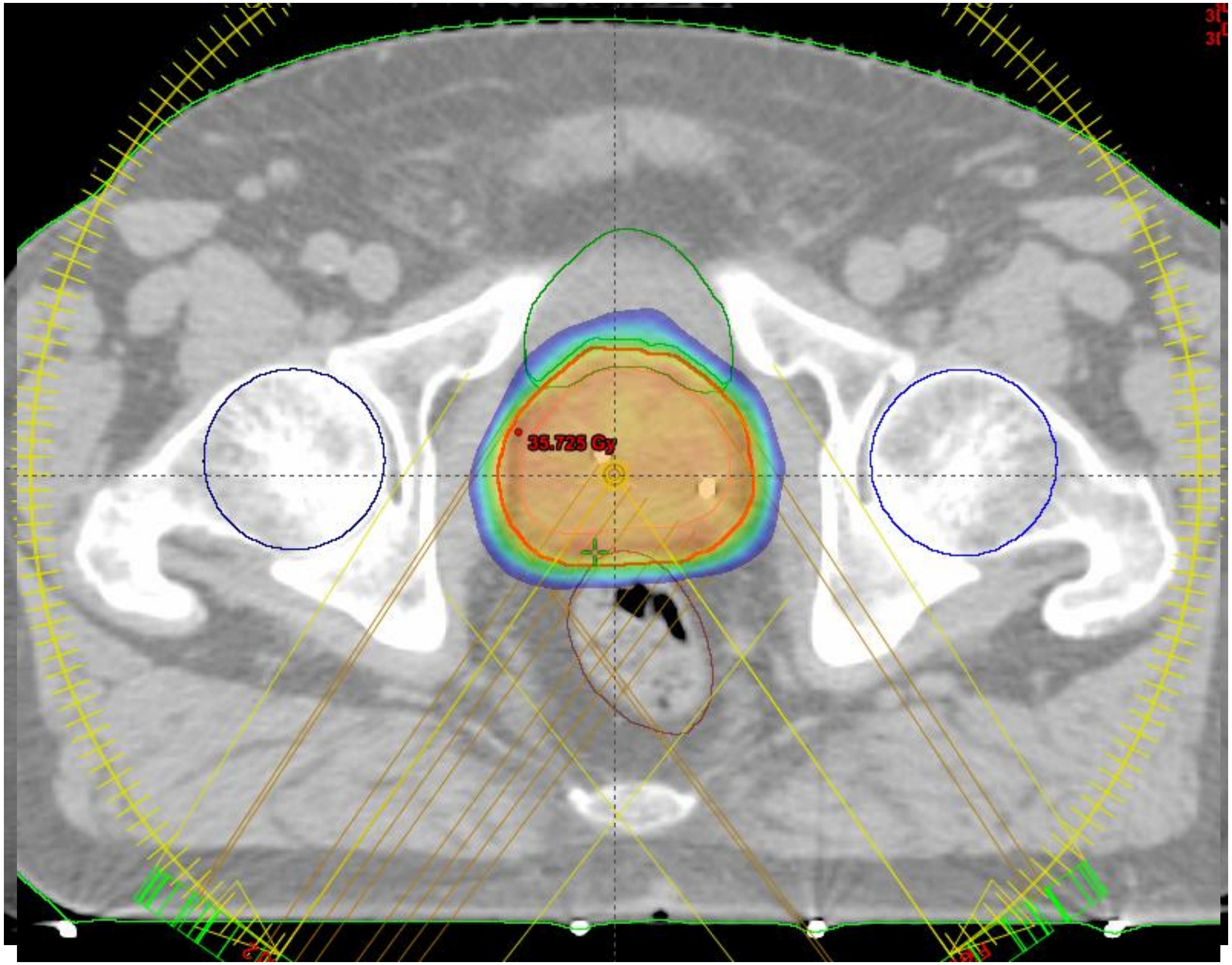


09:38:09 AM ■ Set Zero

Radiation Detected Gating Status: Enabled

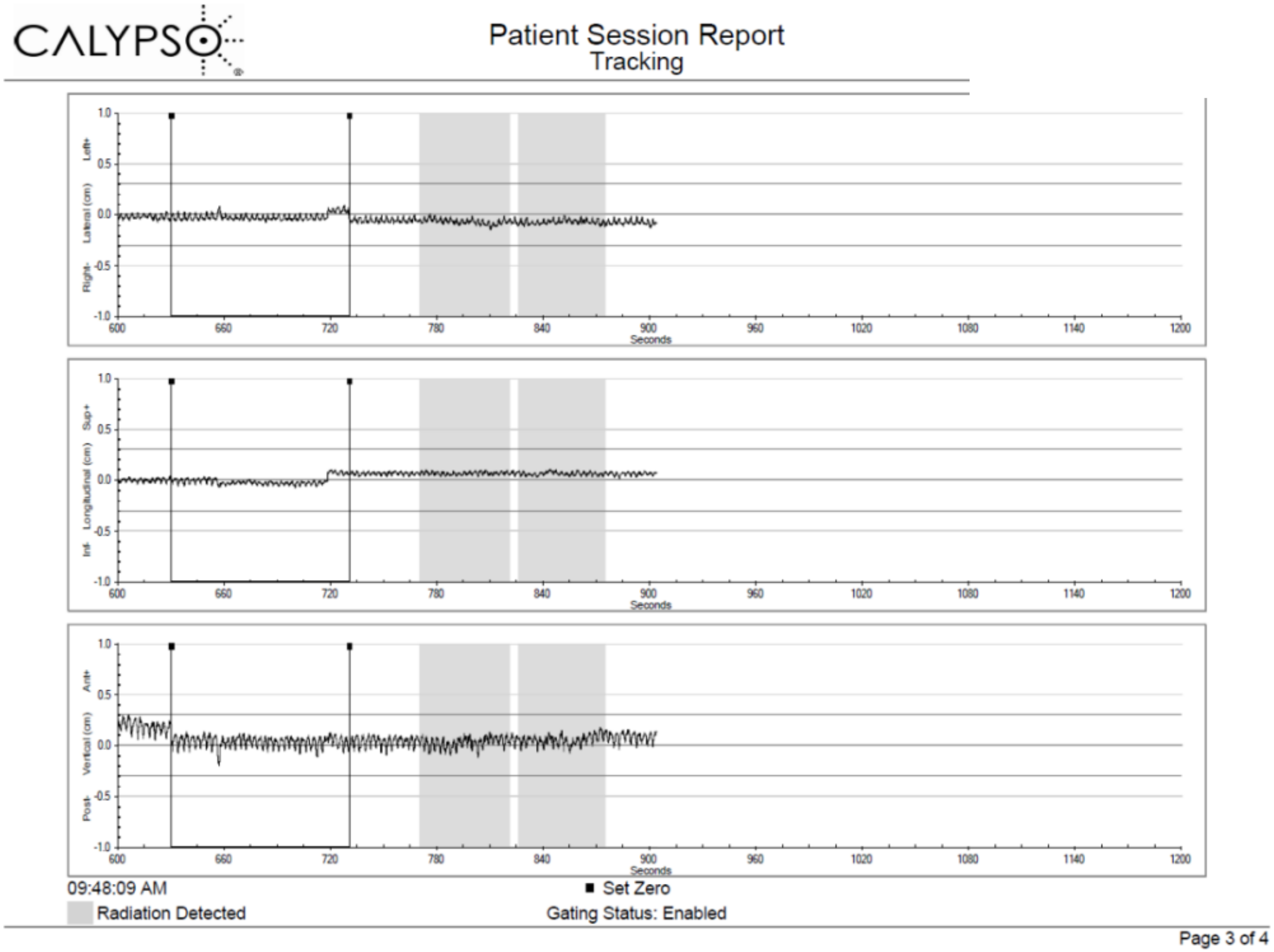
Prostate with Calypso (after 1 min)

HUMANITAS
CANCER CENTER

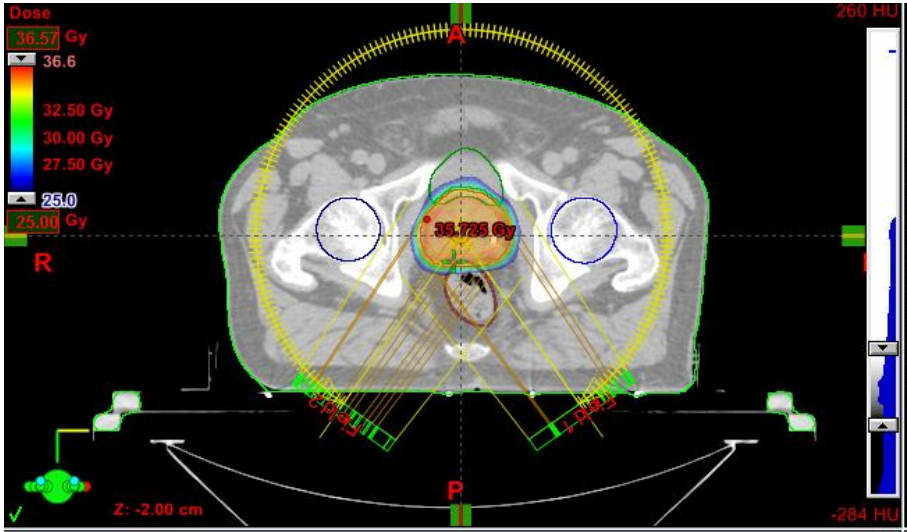


Calypso: Patient tracking

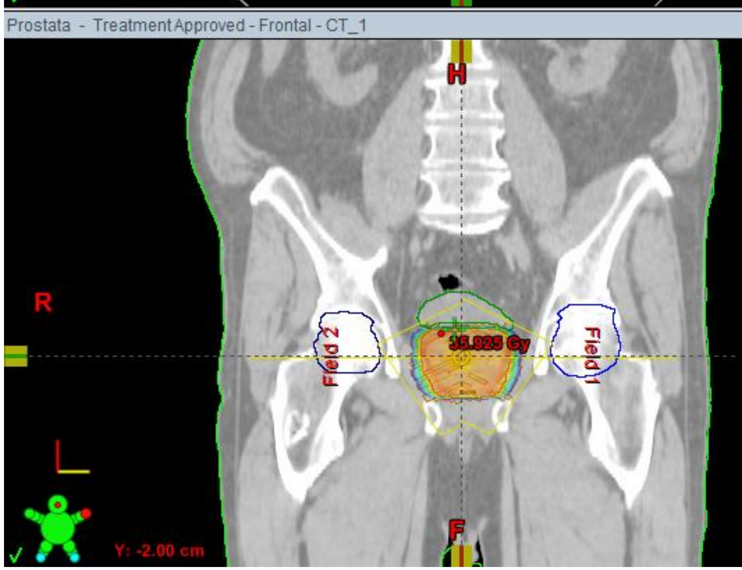
HUMANITAS CANCER CENTER



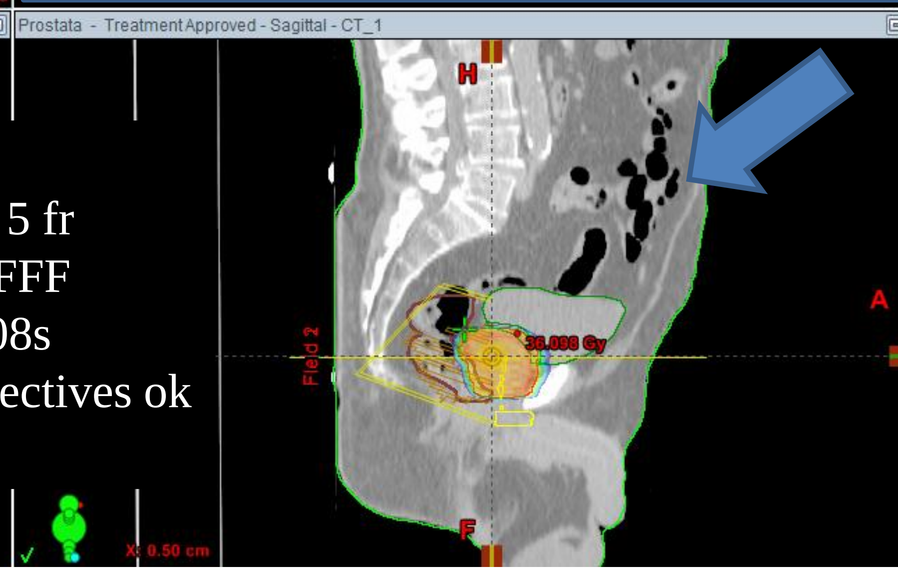
Difficult case@Humanitas



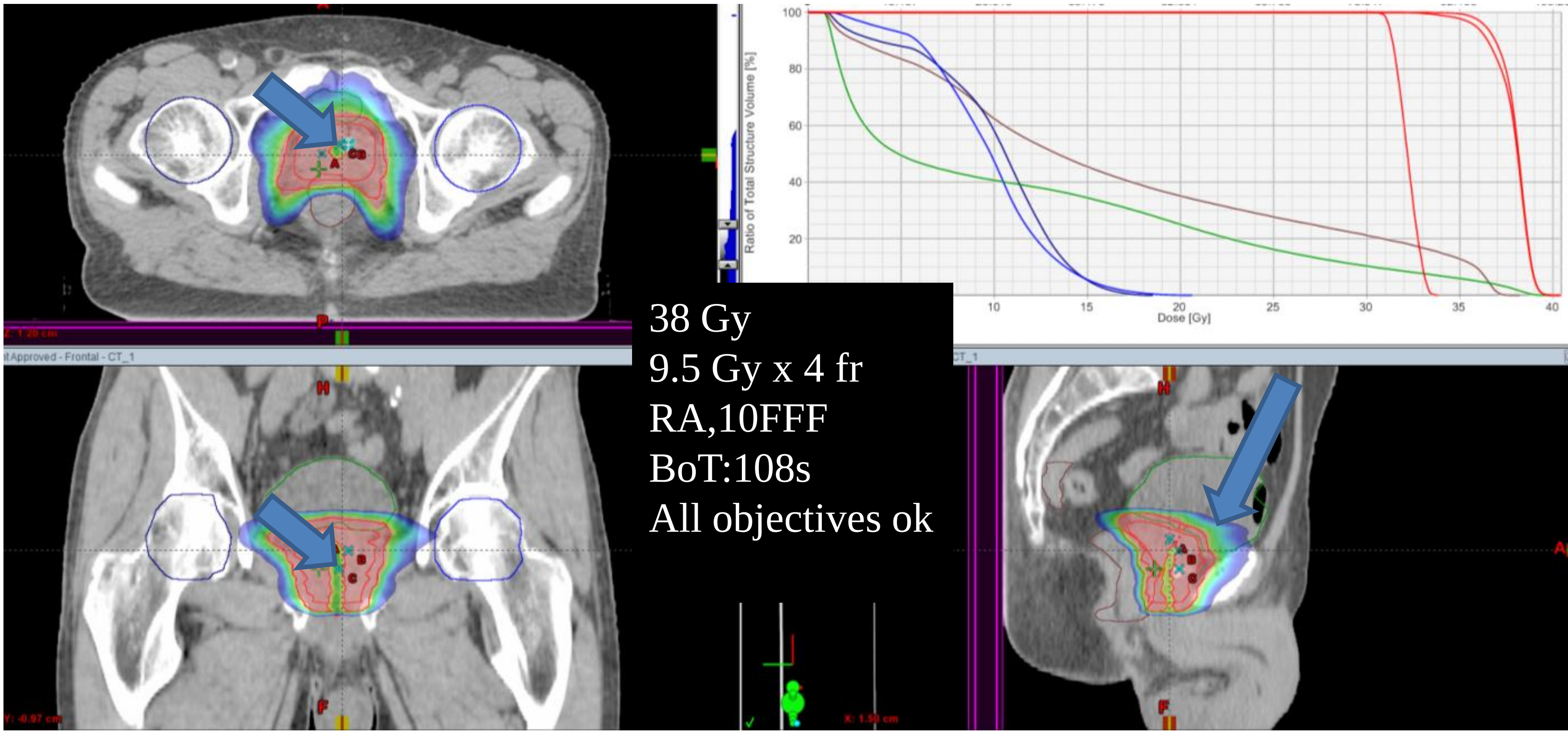
PSA - prostate specific antigen
10.5 ng/ml April 2014
1.4 ng/ml Jan 2015
1.2 ng/ml Jan 2017



35 Gy
7 Gy x 5 fr
RA,10FFF
BoT:108s
All objectives ok



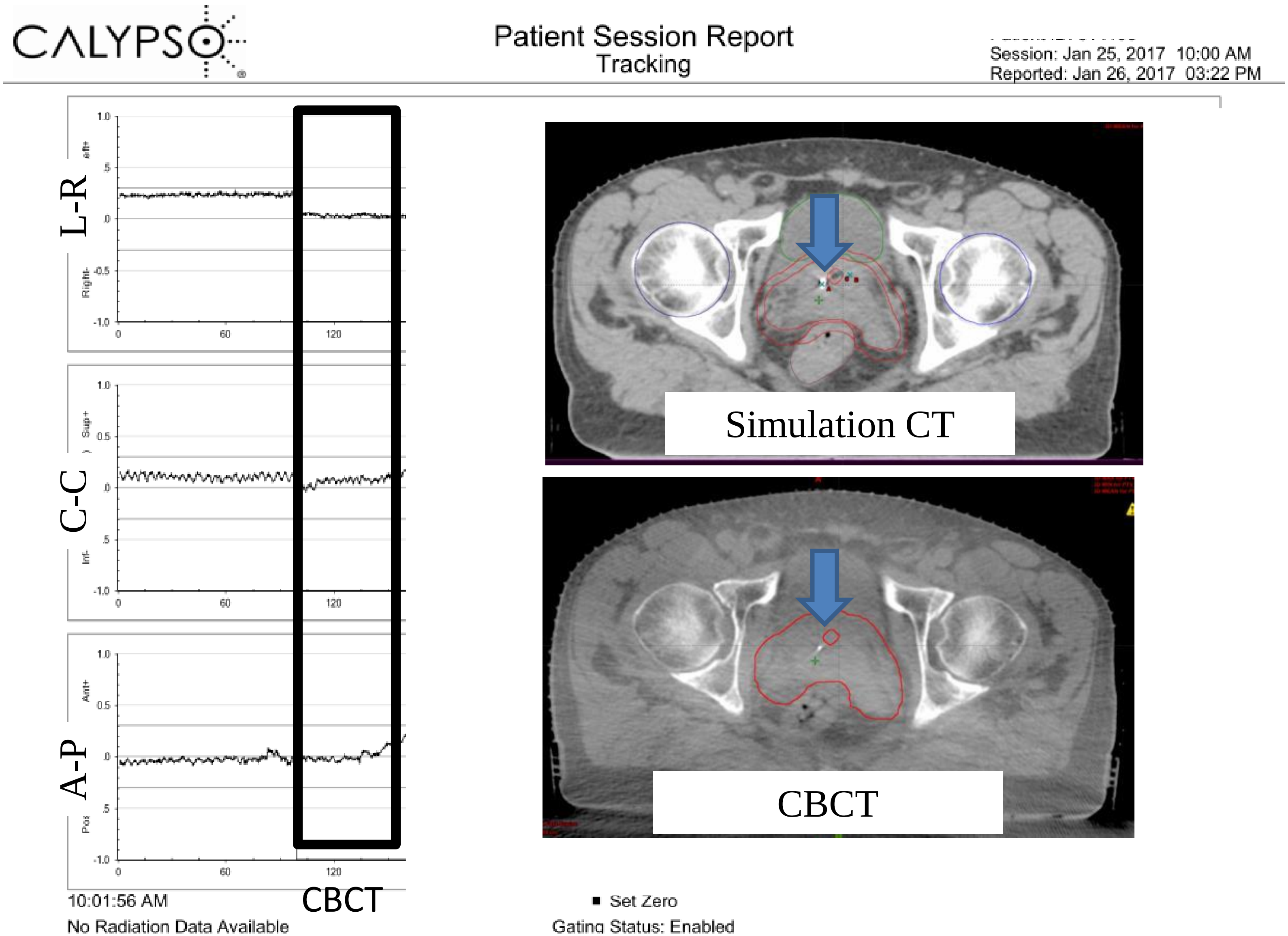
Non-Difficult case@Humanitas



38 Gy
9.5 Gy x 4 fr
RA,10FFF
BoT:108s
All objectives ok

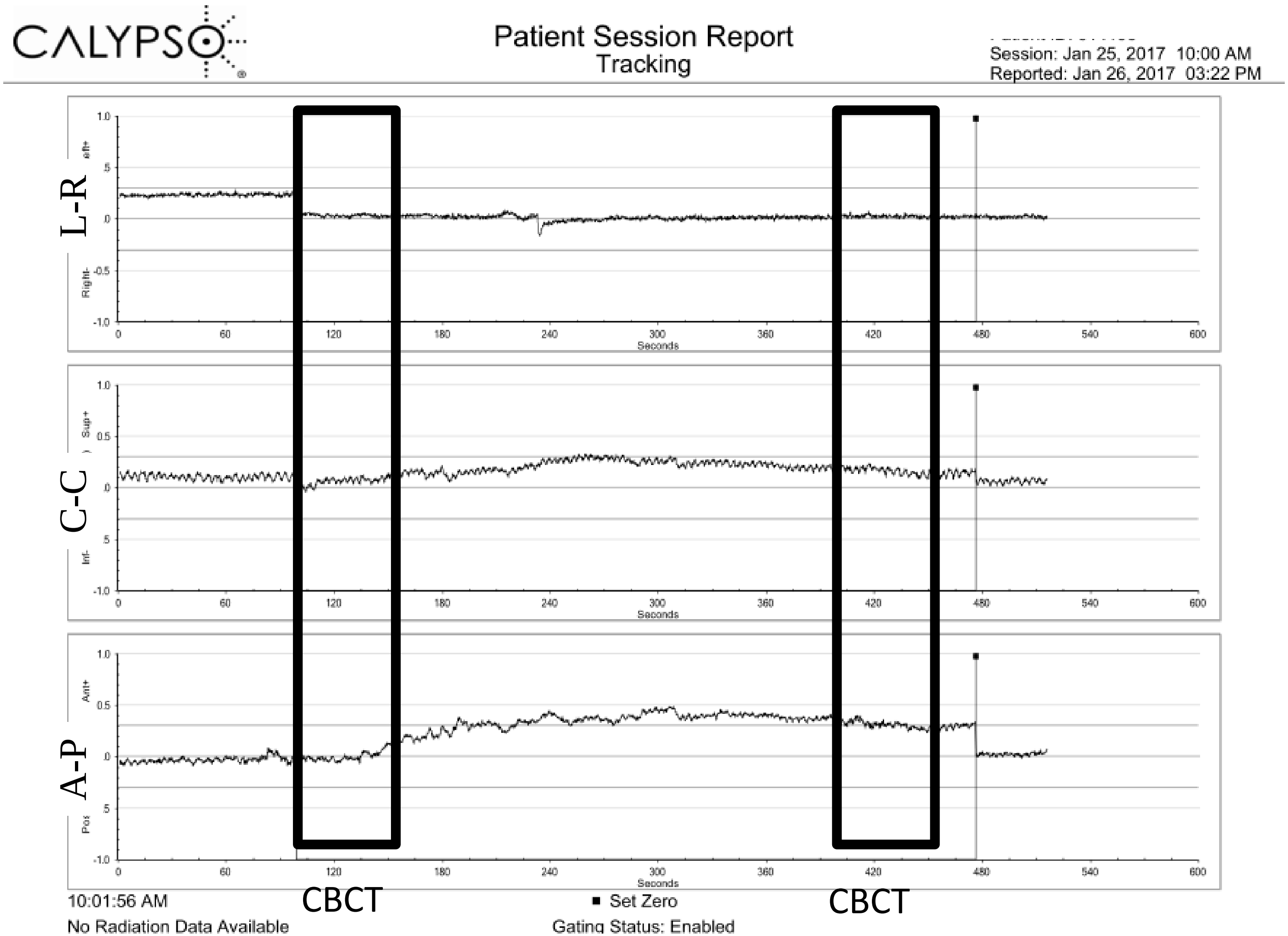
Calypso: Patient tracking

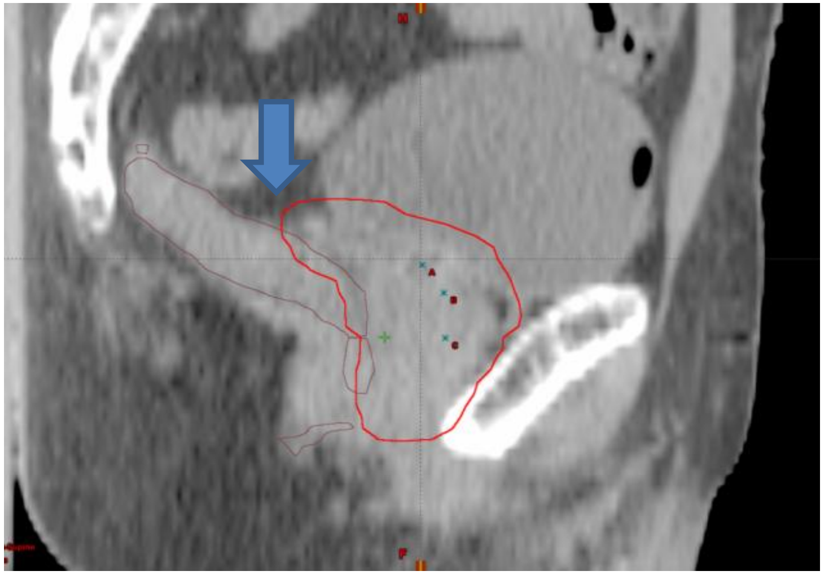
HUMANITAS
CANCER CENTER

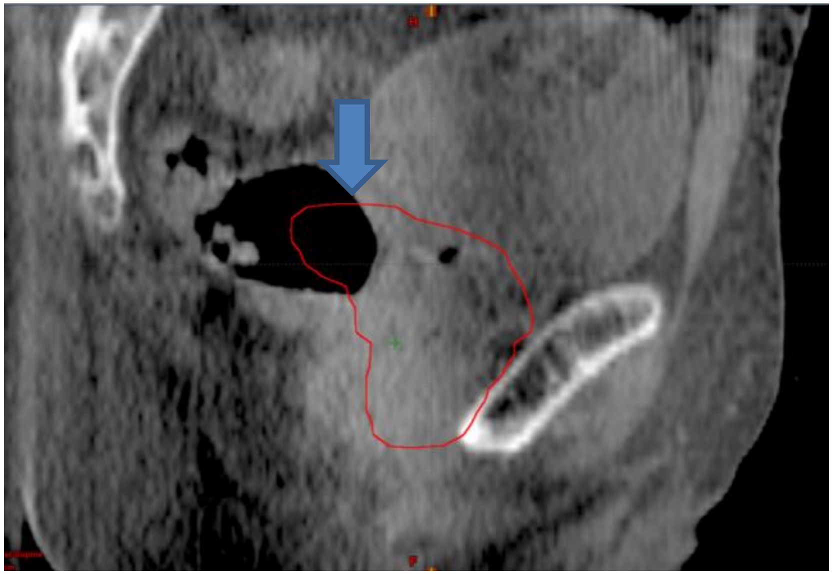


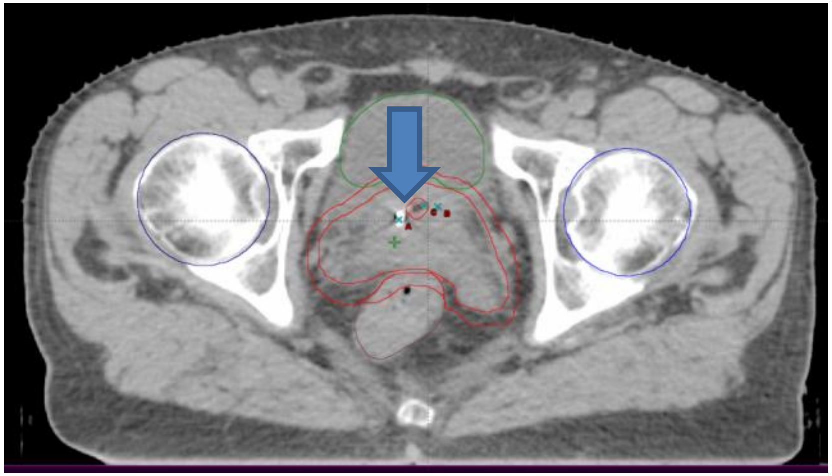
Calypso: Patient tracking

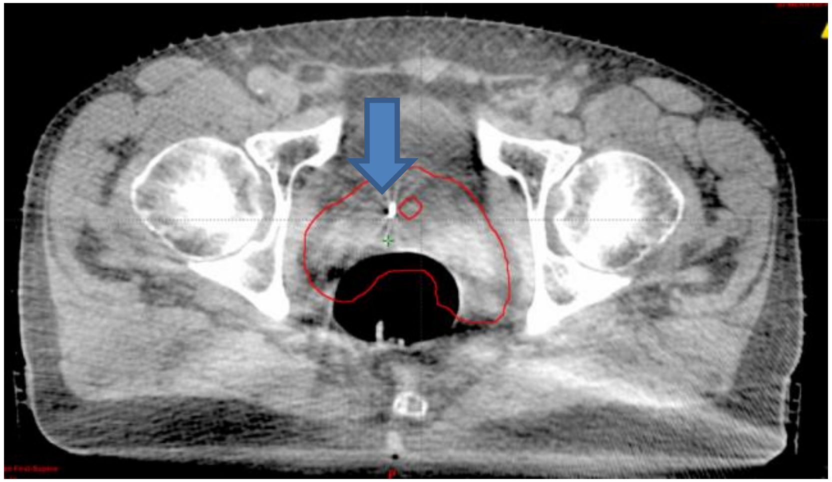
HUMANITAS CANCER CENTER



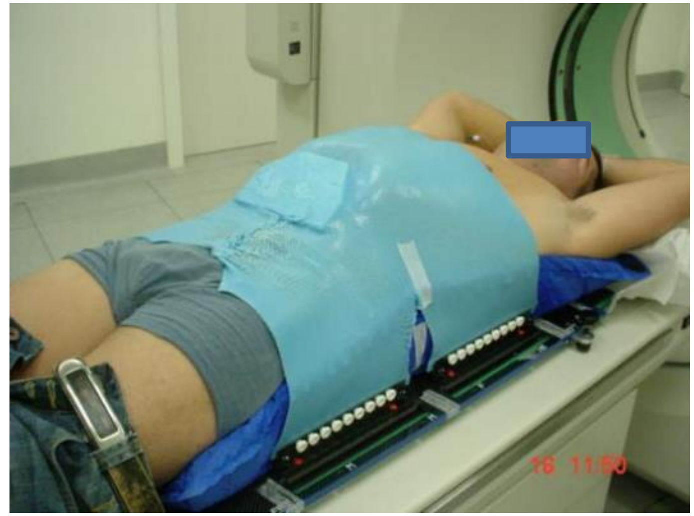


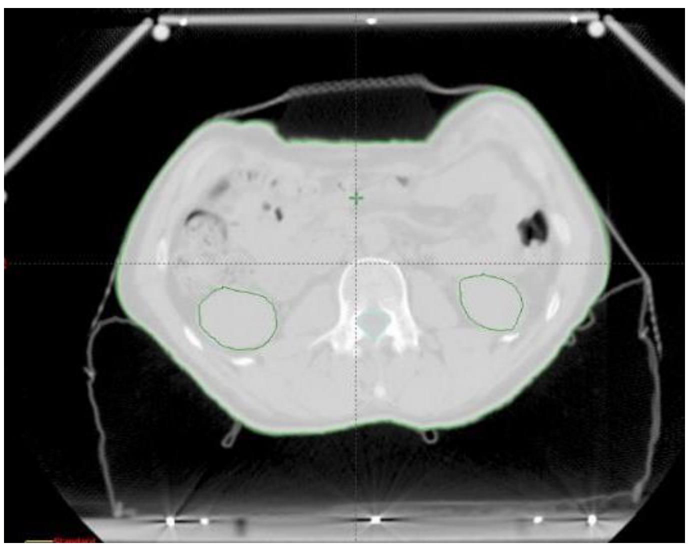






How to limit the motion





Eccles et al, Int J Rad Onc Biol Phys 2010

Abdominal compression: Liver

HUMANITAS CANCER CENTER

PHYSICS CONTRIBUTION

FOUR-DIMENSIONAL COMPUTED TOMOGRAPHY SCAN ANALYSIS OF TUMOR AND ORGAN MOTION AT VARYING LEVELS OF ABDOMINAL COMPRESSION DURING STEREOTACTIC TREATMENT OF LUNG AND LIVER

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Thomas Boike, M.D.,* Stanley Chien, Ph.D.,† Geoffrey Zhang, Ph.D.,*
Ramzi Abdulrahman, M.D.,* and Robert Timmerman, M.D.*

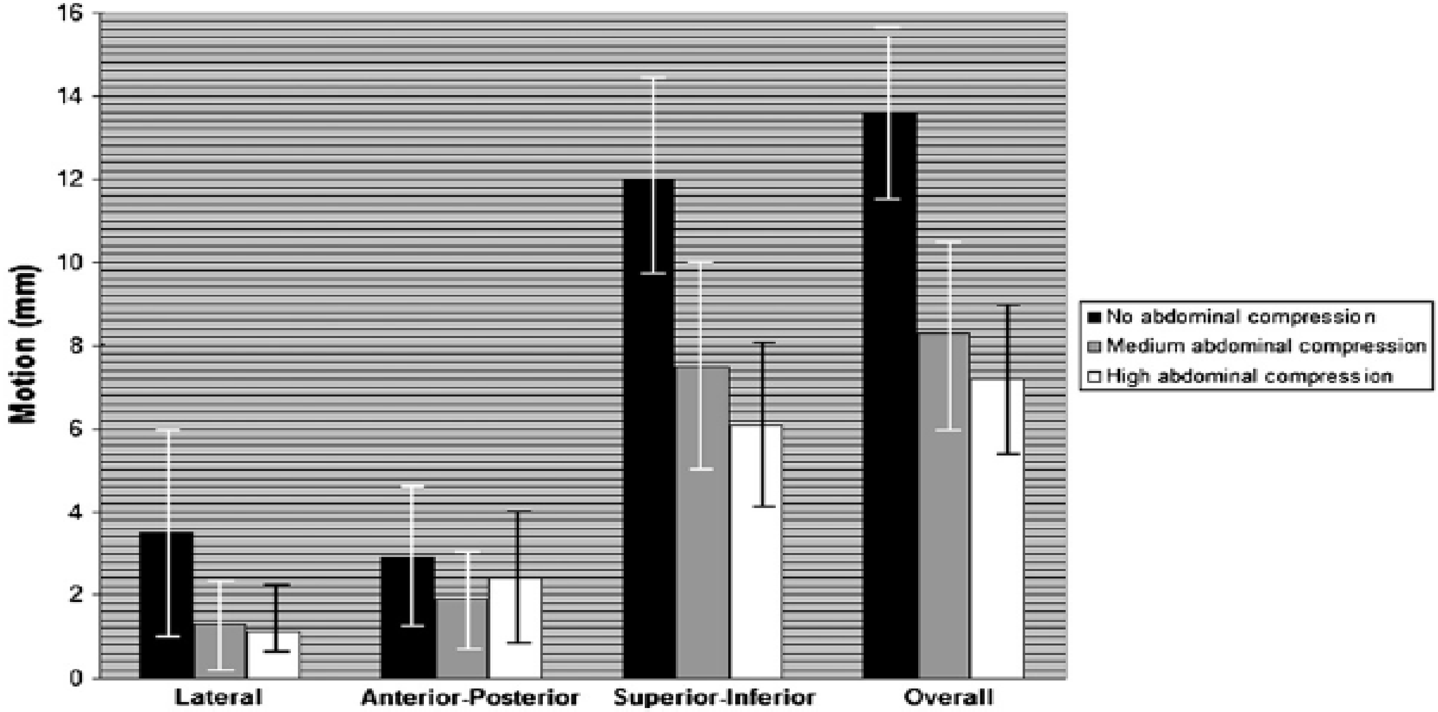
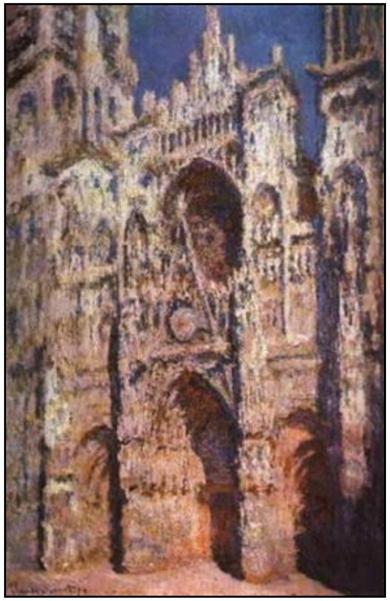


Fig. 2. Tumor motion at varying levels of abdominal compression.

Take home messages

- Lung (but not only) have motion induced by breathing
- Many technologies are available for monitoring:
  Before/During treatment
- Imaging
- Imaging
- Imaging
- Imaging



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Questions?

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