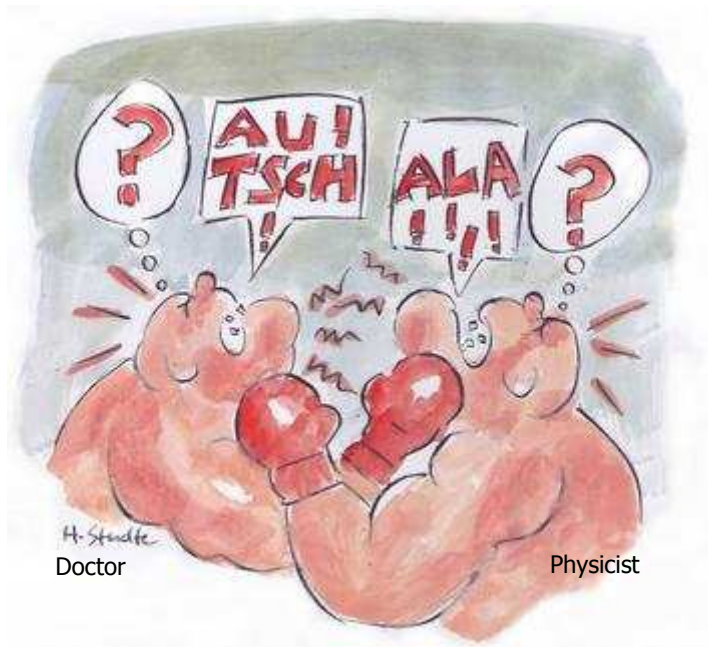


FISICA E RADIOTERAPIA

NUOVE FRONTIERE TRA HIGH TECH E POST GENOMICA

- TOMOTHERAPY: NUOVE POSSIBILITÀ TECNICHE PER NUOVE RISPOSTE A QUESITI CLINICI -

G.Guidi, et.al – Medical Physics Dpt.
Azienda Ospedaliero - Universitaria di Modena - Policlinico



"Fight" with the doctor...

...with Tomo will be possible?

Email: guidi.gabriele@policlinico.mo.it

Email2: gabrieleguidi@yahoo.com

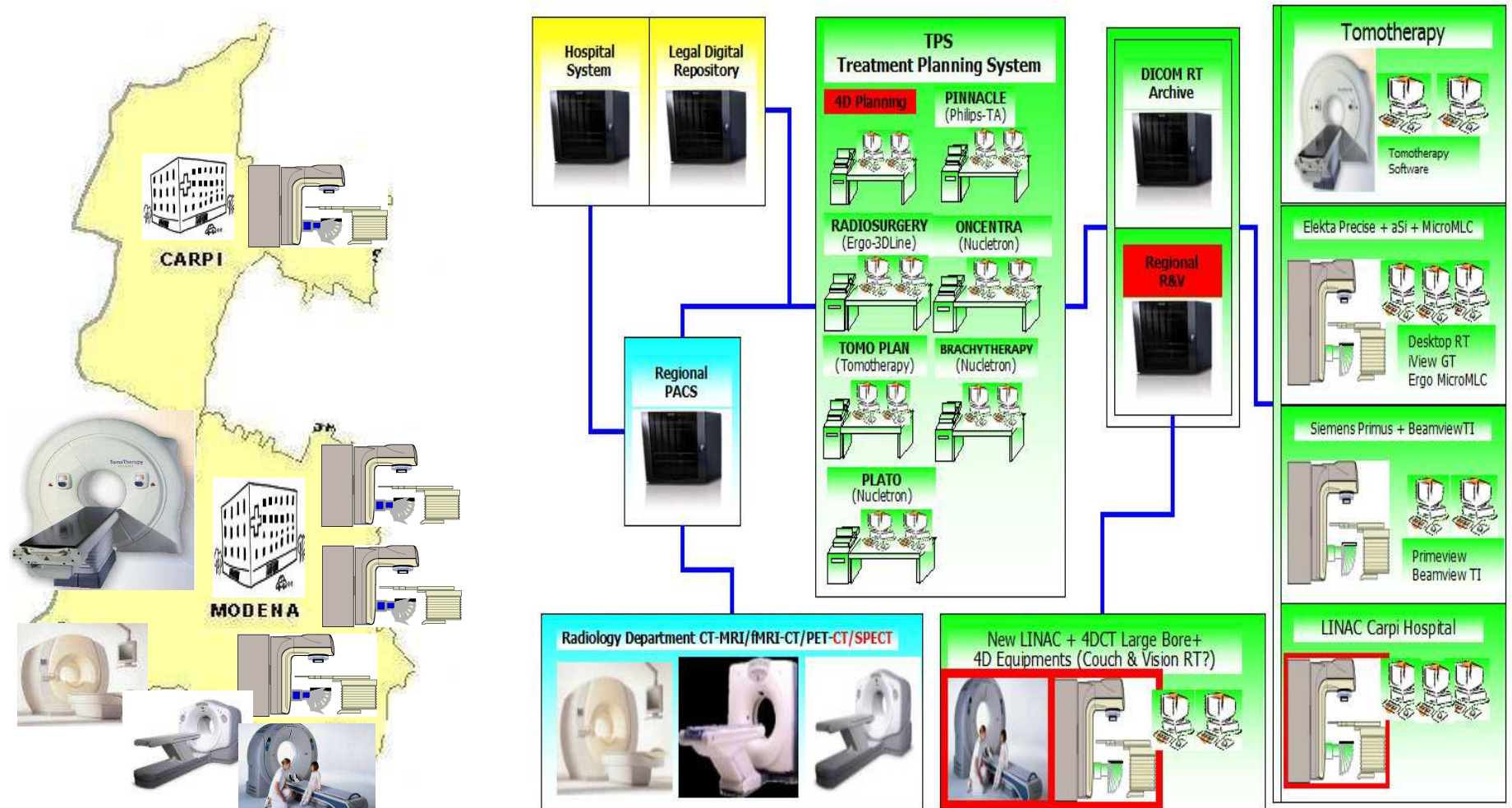
Phone: +390594225699

Special Thanks to Dr.Amadori for part of this presentation

...and the good friendship during this years....



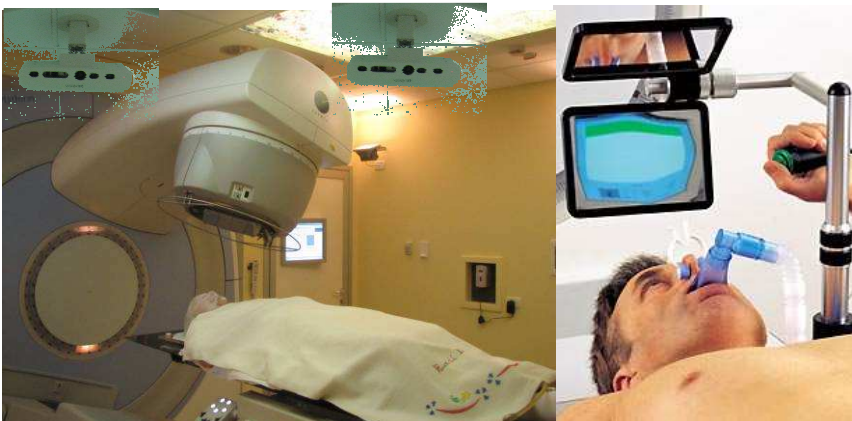
MODENA HUB-SPOKE PROJECT (RADIATION ONCOLOGY HEALTH SERVICES)



4D RADIATION THERAPY VISION (4DRT & 4D TOMOTHERAPY)



TOSHIBA 4D LARGE BORE + VISION RT



4D LINAC + ABC (ACTIVE BREATHING CONTROL)



TOMOTHERAPY + VISIONRT

6 Clinical Research Program to acquire Tomotherapy

1. **NSCLC** : Efficacy and tolerances of exclusive and post-surgery radiation therapy treatments with/without chemo association, using CT-PET and Dynamic IMRT. Patients survival and/or time to progression analysis. Procedures and cost-benefit evaluation. (Prof. L.Fabbri, Prof. U.Morandi, Prof. B.Bagni, Dr. F.Bertoni, Dr. C.Danielli)
2. **H&N** : Radical treatments with concomitant chemotherapy using SIB, Dynamic IMRT, IGRT and Adaptive Radiation Therapy. Treatment conformity index, patients tolerance, efficacy and cost-benefit evaluation using Tomotherapy (Prof. P.F.Conte, Prof. A.Falchi, Dr. F.Bertoni, Dr. C.Danielli)
3. **TBI** (National Health Research - PIO V): Clinical and dosimetric evaluation of Total Body Irradiation using Tomotherapy. Transplant procedure, adequacy and safety evaluations of the treatments using Tomotherapy. Problem solving, efficacy and efficiency. (Prof. G.Torelli, Dr. F.Bertoni, Dr. C.Danielli)
4. **PAEDIATRIC** : Clinical evaluation of paediatric treatments. Paediatric patients management and performance assessment for high conformal and complex treatment using Tomotherapy. Clinical advantages and disadvantages. (Prof. P.Paolucci, Dr. F.Bertoni, Dr. C.Danielli)
5. **BRAIN** : Clinical study for brain tumors using Tomotherapy. Clinical advantages and disadvantages, cost-benefit impact and patient management (Prof. G.Pinna, Dr. L.Mavilla, Prof. B.Bagni, Dr. F.Bertoni, Dr. C.Danielli)
6. **TECHNOLOGY ASSESSMENT**: Technical, dosimetric and cost-benefit evaluation of a Tomotherapy Unit. Routine applicability in a Public Hospital of high conformal, IGRT and Adaptive Radiation Therapy treatments. Develop and optimization of treatment delivery, commissioning and Quality Assurance procedures. Time estimation and requirements to implement protocols and techniques (Dr. F.Bertoni, Dr. C.Danielli, Dr. Eng. M.Lugli)

Research supported by Fondazione Cassa di Risparmio di Modena

3D-IGRT HEALTH TECHNOLOGY ASSESSMENTS (13 REGIONAL RADIATION THERAPY CENTERS COLLABORATION)



Regione Emilia-Romagna



Osservatorio regionale
per l'innovazione



Osservatorio Regionale per l'Innovazione

Osservatorio Regionale per
l'Innovazione

**3D Image Guided – Intensity Modulated
Radiotherapy**

Systematic review of literature on technical performance, safety
and clinical effectiveness

Image Guided Radiation Therapy
(IGRT) in Oncologia

RECOMMENDATIONS FOR FUTURE RESEARCH

- 1) To assess whether radical radiation treatment with IGRT/IMRT in patients with low and intermediate risk prostate cancer improves disease specific survival, compared to treatment with 3D-CRT/IMRT
- 2) To assess whether radical radiation treatment with IGRT/IMRT in patients with primary lung cancer increases local and loco-regional control, compared to treatment with 3D-CRT/IMRT
- 3) To assess whether radical radiation treatment with IGRT/IMRT in patients with head & neck cancer decreases incidence or grade of xerostomy, compared to treatment with 3D-CRT/IMRT

HEALTH TECHNOLOGY ASSESSMENT

FROM TRUCK (WITH TRICK) TO CLINICAL USE

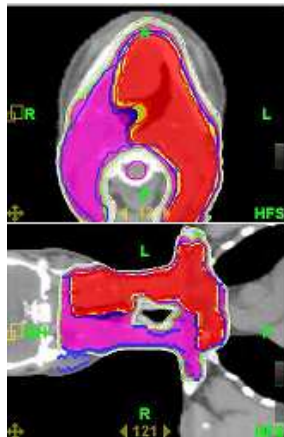
..... 1 Month



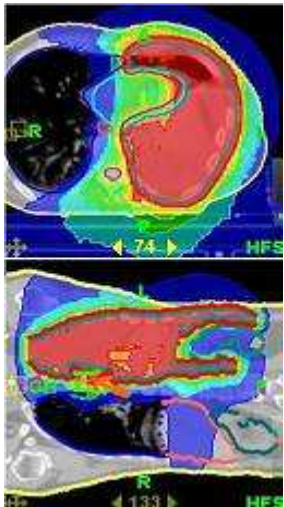
“...Thanks to the perfect cooperation and planning between the hospital and TomoTherapy, we took delivery of our TomoTherapy system and just 30 days later we were already imaging and treating our first patient.” (S. Cencetti - MO)

MADISON, Wis.--(BUSINESS WIRE)--Sept. 10, 2008—
TomoTherapy Incorporated (NASDAQ: TOMO)

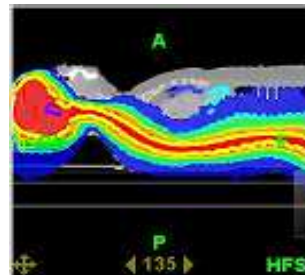
CLINICAL PRACTICE & RESEARCH AREA



H-N



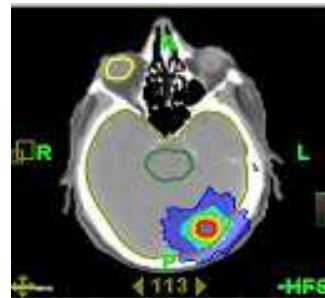
Mesothelioma



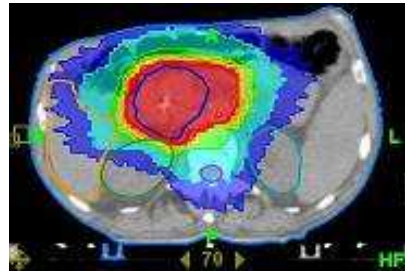
Craniospinal



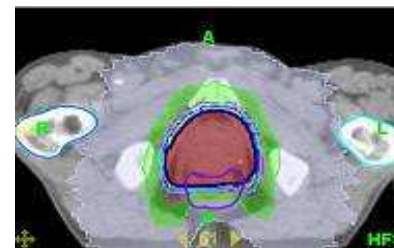
Lung



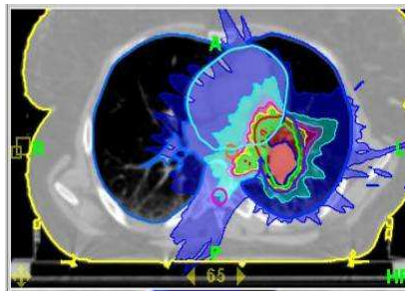
Radiosurgery



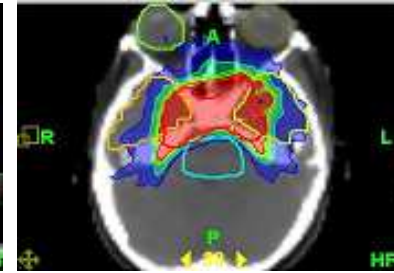
Pancreas



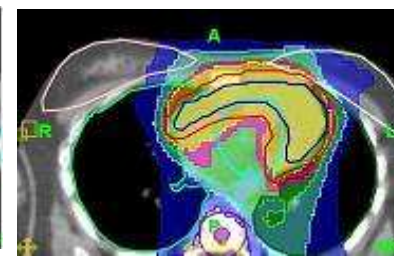
Prostate



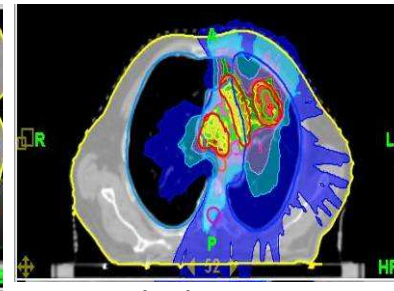
Lung - SBRT



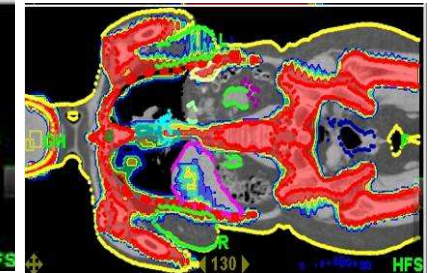
Re-Irradiation



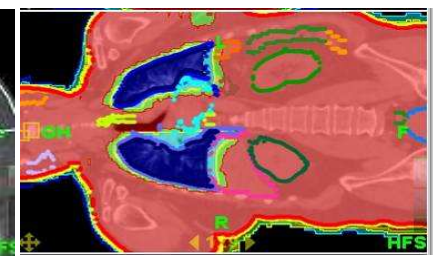
Lymphoma



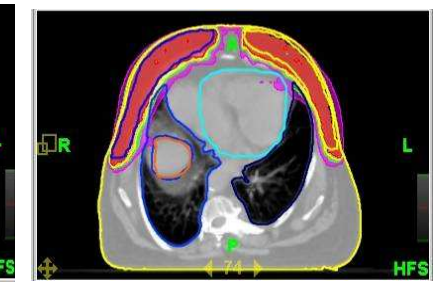
Multiple Lesions



Total Lymphoid Irradiation



Total Body Irradiation



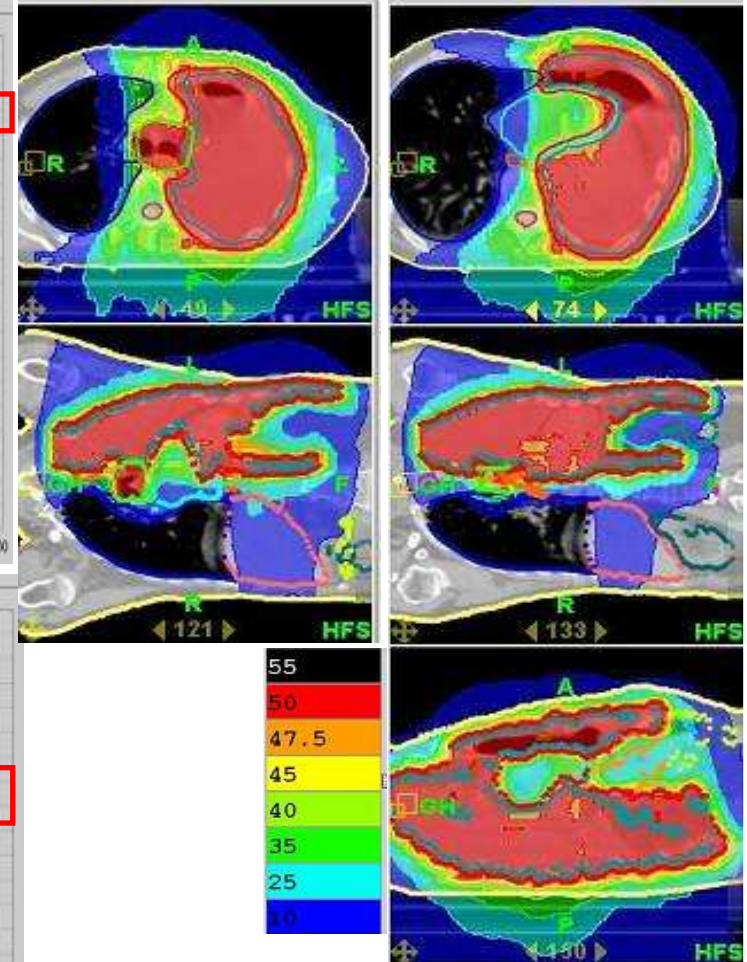
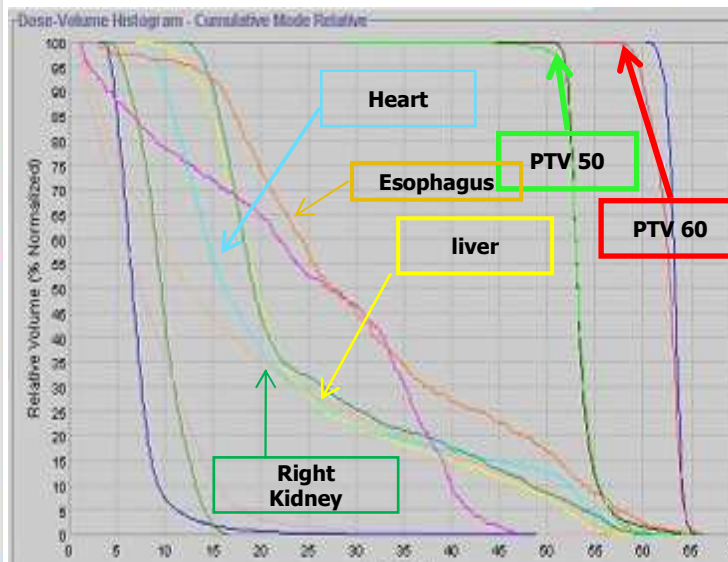
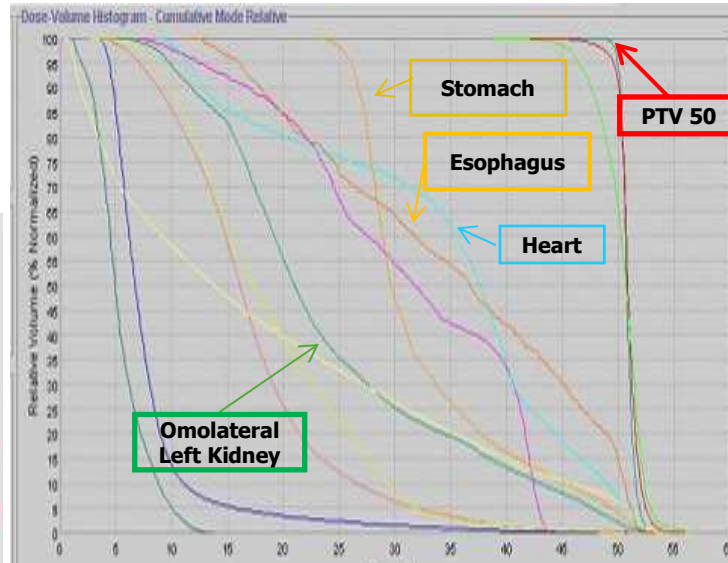
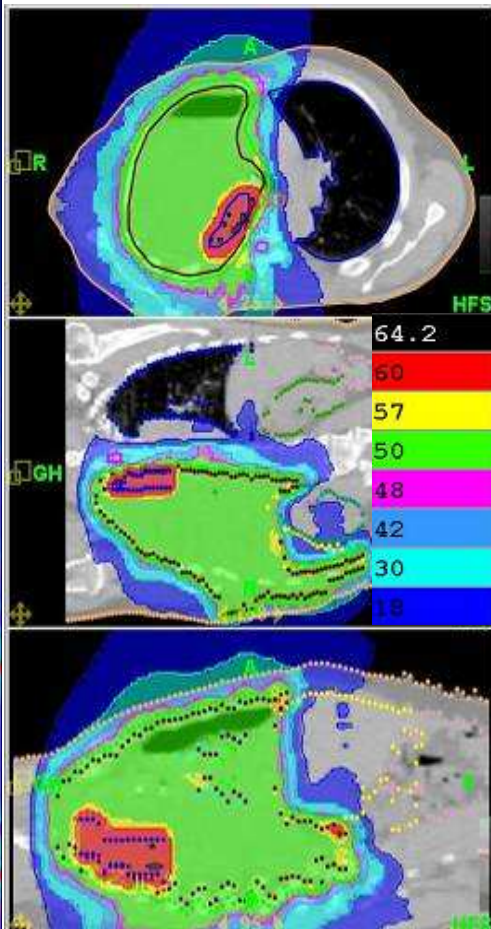
Bilateral Breast

..... preliminary data are consistent with a better tolerance and lower acute toxicity of Tomotherapy treatment compared with other standard treatments using LINAC (3DCRT – IMRT – RCS - SBRT)

MESOTHELIOMA

(SIB: PTV1 60 : 2,4Gy / Fx 25 - PTV2 50 : 2,0Gy / Fx 25) or (Standard: PTV 50 : 2.0 Gy / Fx 25)

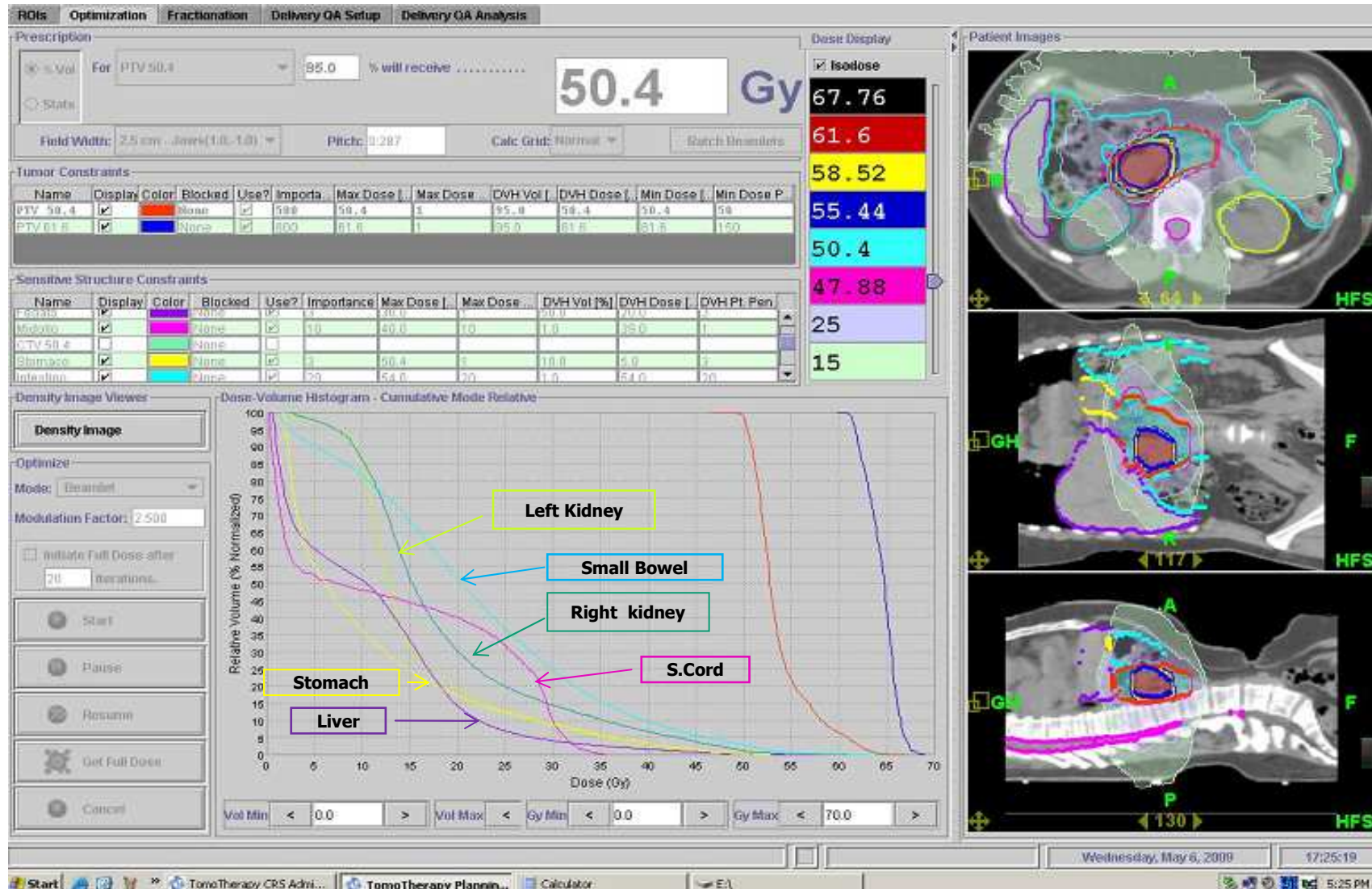
Collaboration with aTrep (Proton Center), Brescia and Florence



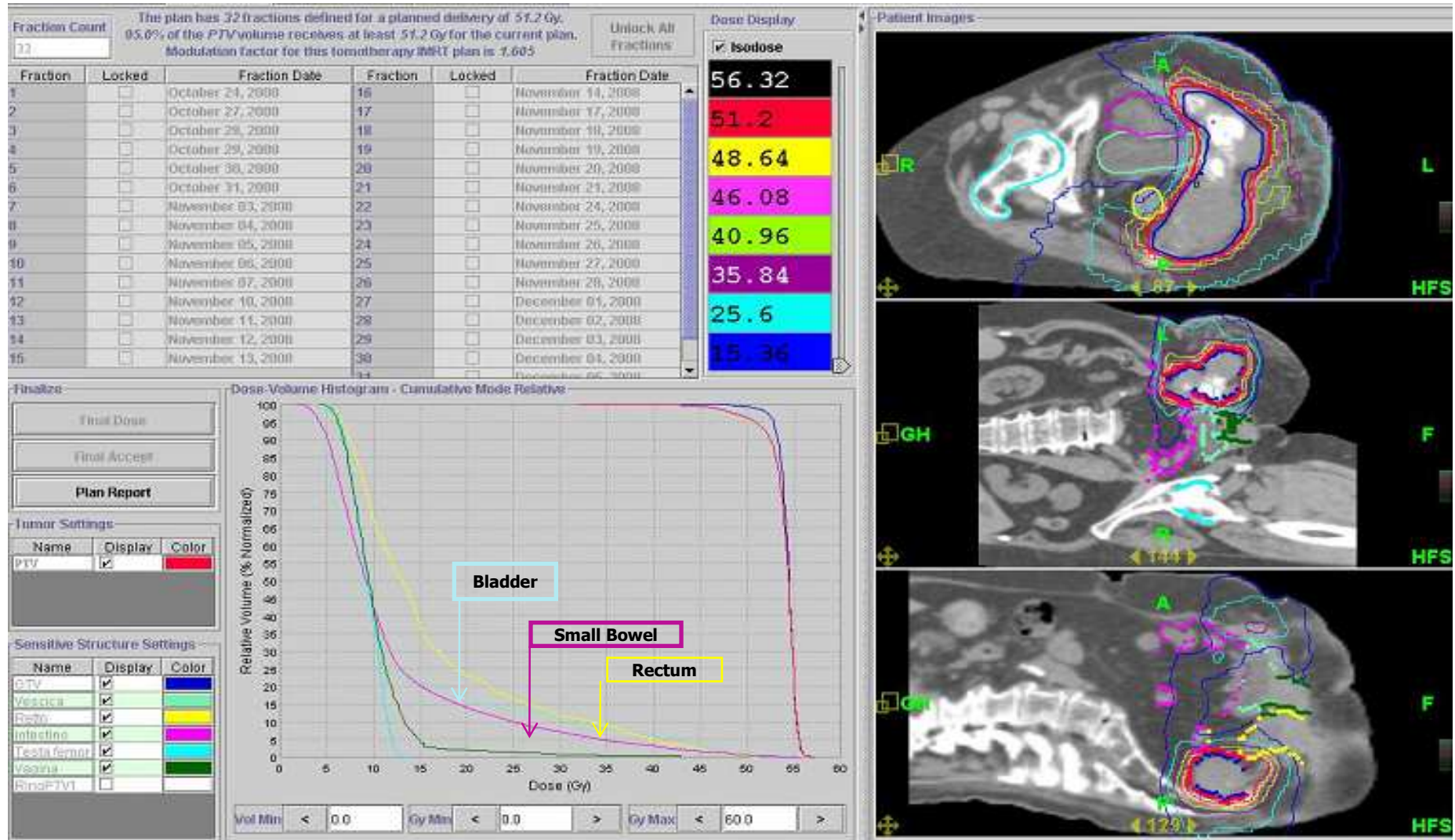
Muticenter Intercomparison for Treatment of the Mesothelioma with IMRT and Tomotherapy.
 G. Guidi, et al Med. Phys. Vol. 36, Issue 6, pag.2666, (June 2009)

UNRESECTABLE PANCREATIC CANCER

SIB: PTV 61,6 : 2,2 Gy / Fx 28 - PTV 50,4 : 1,8 Gy / Fx 28



RE-IRRADIATION: PELVIS SARCOMA PREVIOUSLY TREATED (3DCRT : 50 Gy / 25 Fx + HDR Brachytherapy : 10 Gy / 2 Fx) FOR ENDOMETRIAL CARCINOMA



RE-IRRADIATION: HEAD & NECK

(Standard: 54 Gy / 27 Fx - Hyper-fractionation: 54Gy / 36Fx)

Prescription

For: GTV 95.0 % will receive **54.0 Gy**

Field Width: 1.05 cm Jaw: 0.35; 0.35 Pitch: 0.115 Calc Grid: Fine Match Constraints

Tumor Constraints

Name	Display	Color	Blocked	Use?	Importance	Max Dose []	Max Dose P. []	DVH Vol []	DVH Dose []	Min Dose []	Min Dose P. []
NO De	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input type="checkbox"/>							
NO Rin	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input type="checkbox"/>							
Ponte	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input type="checkbox"/>							
Midolo Alar	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input type="checkbox"/>							

Sensitive Structure Constraints

Name	Display	Color	Blocked	Use?	Importance	Max Dose []	Max Dose P. []	DVH Vol [%]	DVH Dose []	DVH Pt. Pen. []
Occhio Dx	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input checked="" type="checkbox"/>	5	3.0	3	1.0	3.0	1.0
Occhio Sin	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input checked="" type="checkbox"/>	5	3.0	3	1.0	3.0	1.0
Lobo Terna Rl	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input checked="" type="checkbox"/>	8	54.0	8	20.0	20.0	18
Lobo Terna D	<input checked="" type="checkbox"/>	None	<input type="checkbox"/>	<input checked="" type="checkbox"/>	8	54.0	8	20.0	20.0	18

Dose Display

Isodose

- 64.8
- 62.1
- 59.4
- 54
- 51.3
- 48.6
- 40
- 27

Density Image Viewer

Density Image

Optimize Mode: Normal

Modulation Factor: 2.300

Initiate Full Dose after 20 iterations

Start Pause Resume Get Full Dose Cancel

Dose-Volume Histogram - Cumulative Mode Relative

Vol Min < 0.0 > Vol Max < 10 Gy Min < 0.0 > Gy Max < 57.0 >

Patient Images



TEMPORAL LESIONS CLOSE TO VITALS OAR (PTV1:55GY/30FX - PTV2 :66GY/30FX)

The plan has 30 fractions defined for a planned delivery of 54.0 Gy. 95.0% of the PTV54 volume receives at least 54.0 Gy for the current plan. Modulation factor for this tomotherapy IMRT plan is 2.667

Unlock All Fractions

Dose Display

Isodose

Fraction	Locked	Fraction Date	Fraction	Locked	Fraction Date
1	<input type="checkbox"/>	August 31, 2009	16	<input type="checkbox"/>	September 21, 2009
2	<input type="checkbox"/>	September 01, 2009	17	<input type="checkbox"/>	September 22, 2009
3	<input type="checkbox"/>	September 02, 2009	18	<input type="checkbox"/>	September 23, 2009
4	<input type="checkbox"/>	September 03, 2009	19	<input type="checkbox"/>	September 24, 2009
5	<input type="checkbox"/>	September 04, 2009	20	<input type="checkbox"/>	September 25, 2009
6	<input type="checkbox"/>	September 07, 2009	21	<input type="checkbox"/>	September 28, 2009
7	<input type="checkbox"/>	September 08, 2009	22	<input type="checkbox"/>	September 29, 2009
8	<input type="checkbox"/>	September 09, 2009	23	<input type="checkbox"/>	September 30, 2009
9	<input type="checkbox"/>	September 10, 2009	24	<input type="checkbox"/>	October 01, 2009
10	<input type="checkbox"/>	September 11, 2009	25	<input type="checkbox"/>	October 02, 2009
11	<input type="checkbox"/>	September 14, 2009	26	<input type="checkbox"/>	October 05, 2009
12	<input type="checkbox"/>	September 15, 2009	27	<input type="checkbox"/>	October 06, 2009
13	<input type="checkbox"/>	September 16, 2009	28	<input type="checkbox"/>	October 07, 2009
14	<input type="checkbox"/>	September 17, 2009	29	<input type="checkbox"/>	October 08, 2009
15	<input type="checkbox"/>	September 18, 2009	30	<input type="checkbox"/>	October 09, 2009

Finalize

Final Dose

Final Accept

Plan Report

Tumor Settings

Name	Display	Color
CTV86	<input checked="" type="checkbox"/>	Blue
PTV54	<input checked="" type="checkbox"/>	Red

Sensitive Structure Settings

Name	Display	Color
Chiasma	<input checked="" type="checkbox"/>	Blue
Optical Nerve	<input checked="" type="checkbox"/>	Green
Cord	<input checked="" type="checkbox"/>	Magenta
Brainstem	<input checked="" type="checkbox"/>	Yellow

Dose-Volume Histogram - Cumulative Mode Relative

Optical Nerve < 56Gy

Cord < 35Gy

Brainstem

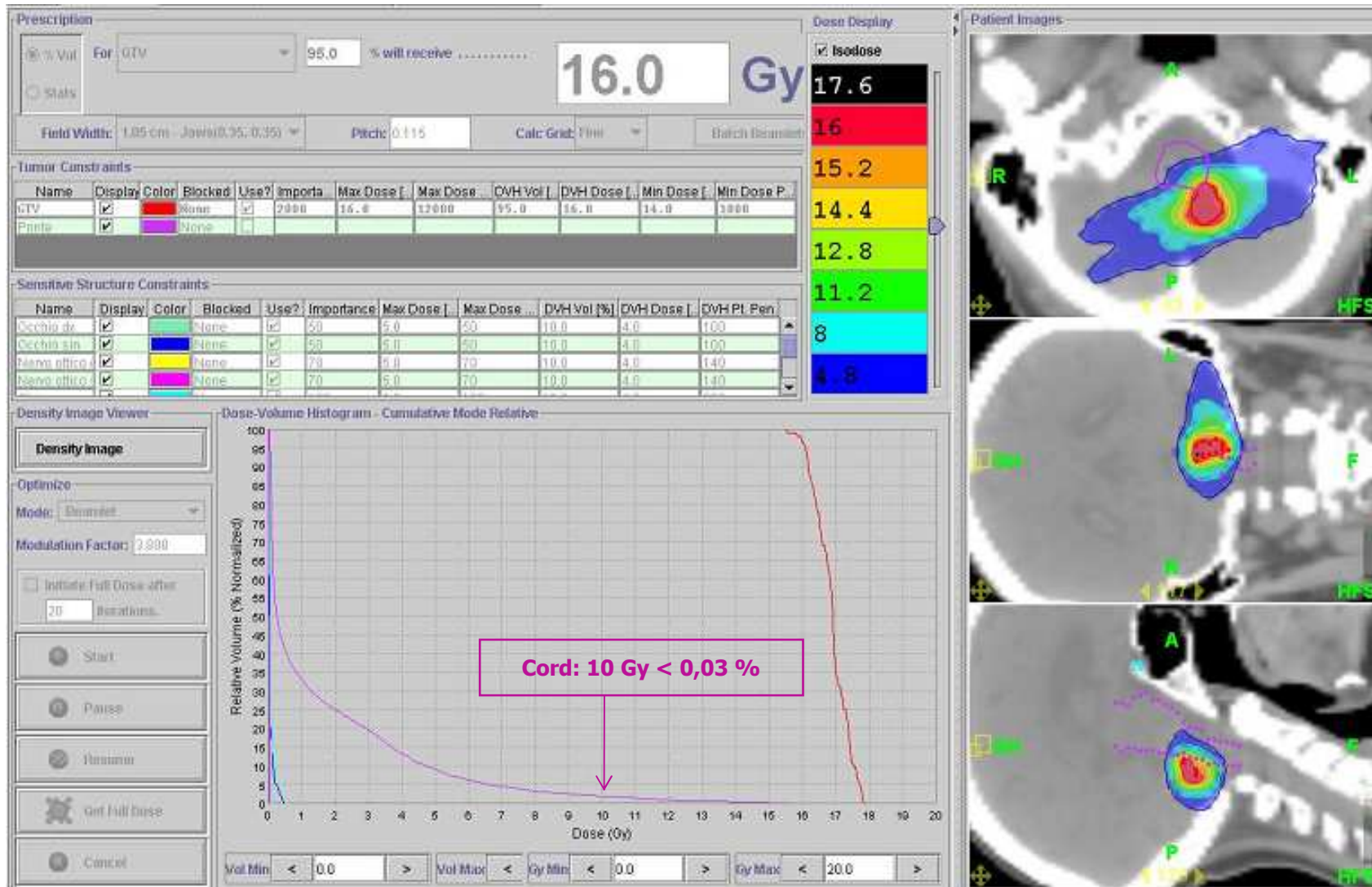
Vol Min < 0.0 > Vol Gy Min < 0.0 > Gy Max < 75.0 >

Patient Images

Monday, September 7, 2009 14:52:46

2:52 PM

RADIOSURGERY RE-TREATMENT (16-22Gy / Fx @ 95% of the Volume) (PREVIOUS WBRT 30 Gy / 10 FX + RS WITH MicroMLC+LINAC 18 Gy / 1 Fx – CORD DOSE : 42 Gy)



STOMACH (PTV1: 53.75GY/ 25FX – PTV2: 45GY/25FX)

Prescription

% Vol For PTV53 95.0 % will receive **53.75 Gy**

Stats

Field Width: 2.5 cm - Jaws(1.0,-1.0) Pitch: 0.213 Calc Grid: Normal Batch Beamlets

Tumor Constraints

Name	Display	Color	Blocked	Use?	Impor...	Max Dose [...]	Max Dose P...	DVH Vol [...]	DVH Dose [...]	Min Dose [...]	Min Dose P...
PTV53	<input checked="" type="checkbox"/>	Red	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	200	53.75	500	95.0	53.75	53.75	500
PTV45	<input checked="" type="checkbox"/>	Blue	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	100	45.0	320	95.0	45.0	45.0	200
Midollo	<input checked="" type="checkbox"/>	Magenta	<input checked="" type="checkbox"/>	<input type="checkbox"/>							

Sensitive Structure Constraints

Name	Display	Color	Blocked	Use?	Importa...	Max Dose [...]	Max Dose P...	DVH Vol [%]	DVH Dose [...]	DVH Pt. Pen.
MidExo	<input checked="" type="checkbox"/>	Green	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	3	35.0	3	1.0	32.0	5
Rene sx	<input checked="" type="checkbox"/>	Light Green	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	2	50.0	2	15.0	15.0	20
Rene dx	<input checked="" type="checkbox"/>	Yellow	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	2	53.0	2	20.0	15.0	20
PolmoneSin	<input checked="" type="checkbox"/>	Dark Blue	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1	45.0	1	10.0	10.0	1

Density Image Viewer

Density Image

Optimize

Mode: Beamlet

Modulation Factor: 3.200

Initiate Full Dose after 20 iterations.

Start

Pause

Resume

Get Full Dose

Cancel

Dose Display

Isodose

59.125

53.75

51.062

45

42

30

20

15

Patient Images

Dose-Volume Histogram - Cumulative Mode Relative

Relative Volume (% Normalized)

Dose (Gy)

Kidneys 20%Vol < 22Gy

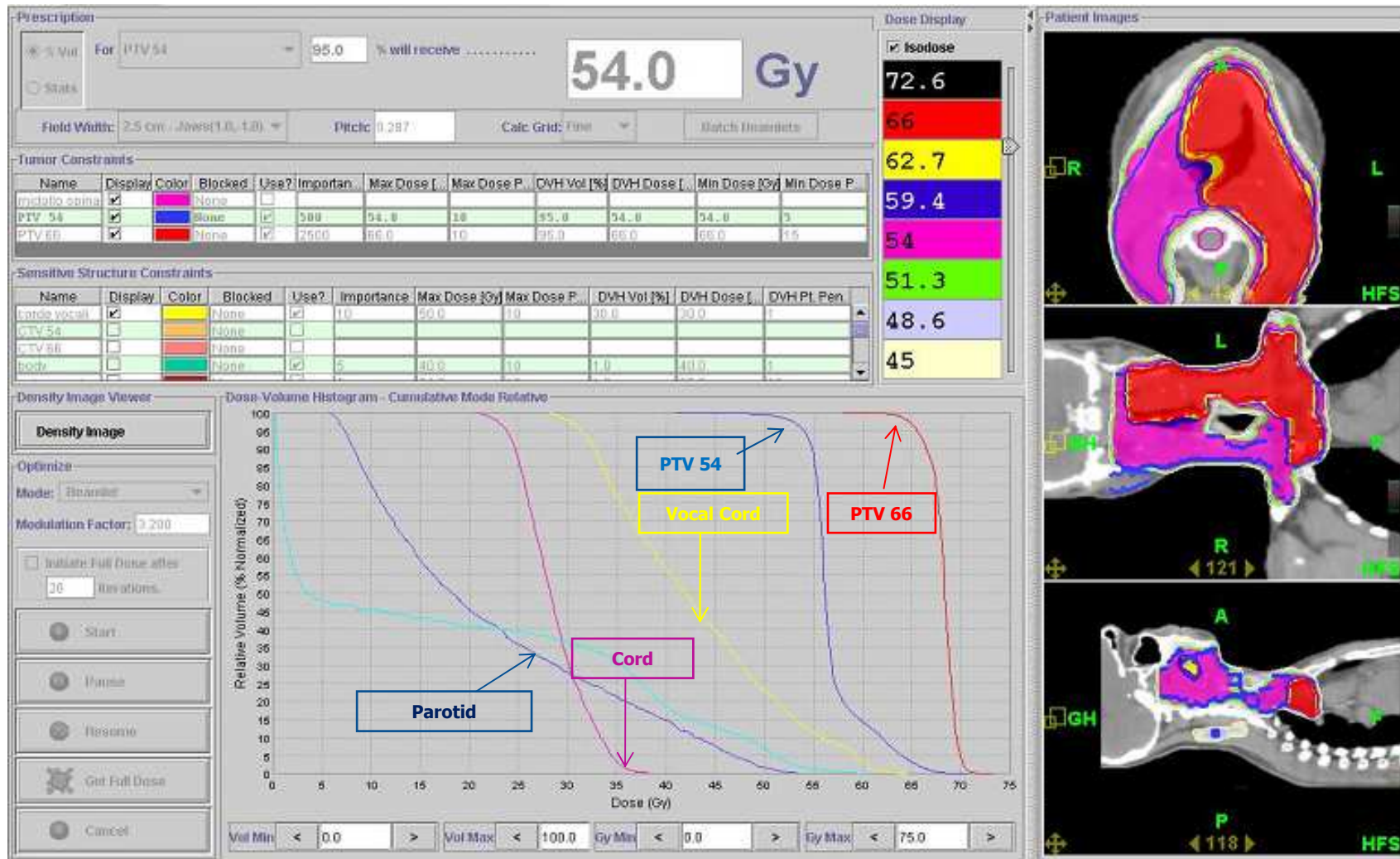
Liver 20%Vol < 30Gy

Cord < 22Gy

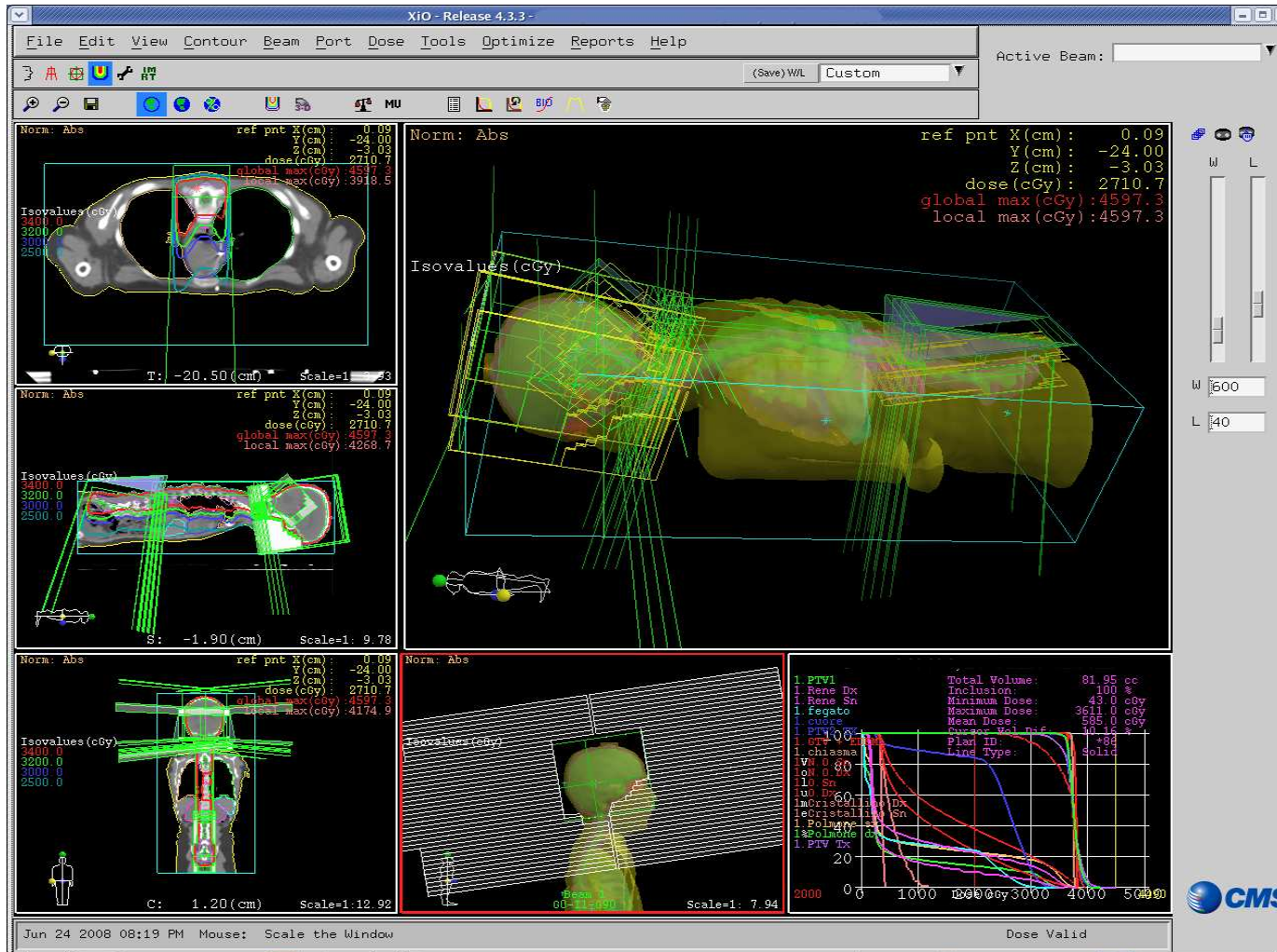
Vol Min < 0.0 > Vol Max < 10 Gy Min < 0.0 > Gy Max < 60.0 >

HEAD & NECK WITH CONCOMITANT CHT + RT (SIB)
66 Gy IN 30 / Fx (2,2 Gy/Fx) TO T AND N+ 54 Gy IN 30 / Fx (1,8 Gy/Fx) TO RIGHT CERVICAL NODES

RELAPSE TO ORIGINAL SITE AND TO LEFT CERVICAL NODES FROM SQUAMOS CARCINOMA OF LEFT BODY TONGUE (R C T2 N2B M0) PREVIOUSLY MANAGED WITH SURGERY ALONE



PAEDIATRIC CRANIO – SPINAL (Linac)



Standard Treatment @ Modena

1. Linac 6MV
2. Prone Position
3. Multiple field junction
4. 3 Split-beam (1cm for each day)
5. No-Coplanar Beam
6. Multiple Isocenter (no SSD=100cm)
7. PTV Margin 1cm
8. Conformal field
9. Portal verification of each junction
10. Procedure time 35 - 45min

..not anymore used after the Tomotherapy installation..

PAEDIATRIC CRANIO – SPINAL (Tomotherapy)

Tomotherapy Planning Station -- Policlinico di Modena

Patient: No Photo
 DOB: Sex: M Plan: Plan_02
 ID: Plan status: Approved
 Plan date: Jun 13, 2008 3:57:17 PM DQA plan:
 Oncologist: Patient position: HFP
 Disease: CT1

What's Next
 Define Rx Constraints
 Define constraints for tumors.
 Define constraints for sensitive structures.
 Set isodose display options.
 When you are satisfied, click **Start** to begin optimization.

User Name: System User

Prescription
 For PTV1 95.0 % will receive **36.0 Gy**
 Field Width: 5.02 cm - Jaws(2.1, 2.1) Pitch: 0.500 Calc Grid: Normal Batch Beamlets

Tumor Constraints

Name	Display	Color	Blocked	Use?	Importan...	Max Dose [...]	Max Dose P...	DVH Vol [...]	DVH Dose [...]	Min Dose [...]	Min Dose P...
PTV1	<input checked="" type="checkbox"/>	Red	None	<input checked="" type="checkbox"/>	1000	36.0	1000	95.0	36.0	36.0	2000

Sensitive Structure Constraints

Name	Display	Color	Blocked	Use?	Importance	Max Dose [...]	Max Dose P...	DVH Vol [...]	DVH Dose [...]	DVH Pt. Pen.
Body	<input checked="" type="checkbox"/>	Yellow	None	<input checked="" type="checkbox"/>	1	1.0	1	1.0	1.0	1
GTV + EDEM	<input checked="" type="checkbox"/>	Red	None	<input checked="" type="checkbox"/>	1	1.0	1	1.0	1.0	1
PTV2 TX	<input checked="" type="checkbox"/>	Blue	None	<input checked="" type="checkbox"/>	1	1.0	1	1.0	1.0	1
Renal Dy	<input checked="" type="checkbox"/>	Purple	None	<input checked="" type="checkbox"/>	200	35.0	100	5.0	10.0	1000

Density Image Viewer
 Optimize Mode: Beamlet Modulation Factor: 2.000
 Initiate Full Dose after 20 iterations
 Start, Pause, Resume, Get Full Dose, Cancel

Dose-Volume Histogram - Cumulative Mode Relative
 Relative Volume (% Normalized) vs Dose (Gy)

Patient Images
 Axial, Coronal, and Sagittal views showing dose distribution and target/organ at risk contours.

Tuesday, June 24, 2008 20:13:12

Tomotherapy Simulation

1. Prone Position
2. No Multiple field junction
3. No Split-beam
4. No-Coplanar Beam
5. No Multiple Isocenter
6. PTV Evaluation
 - i. Margin 1cm
 - ii. Margin 0cm
7. High Conformal
8. MVCT verification and adjustment
9. Procedure time 20-30min

TOMOTHERAPY VS. LINAC

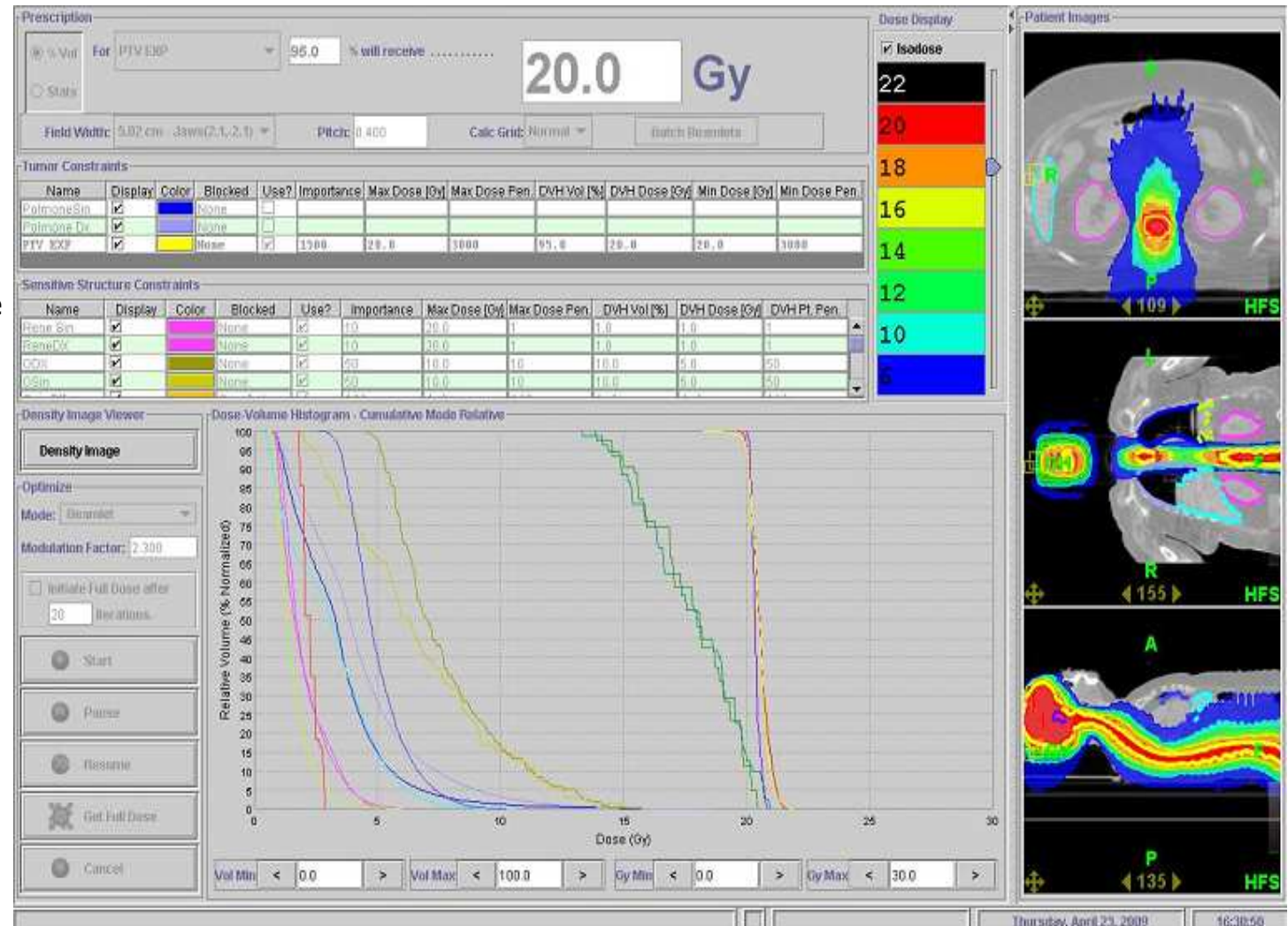
Lung, Hearth, Liver, Eyes, and Kidneys less dose/volume; for Hearth and Liver decrease the DMax

- Optical Nerve : same Dmax but less dose/volume
- Lens: increase the Dmax Dose, but under the max toxicity value (also with Complete Block Option)

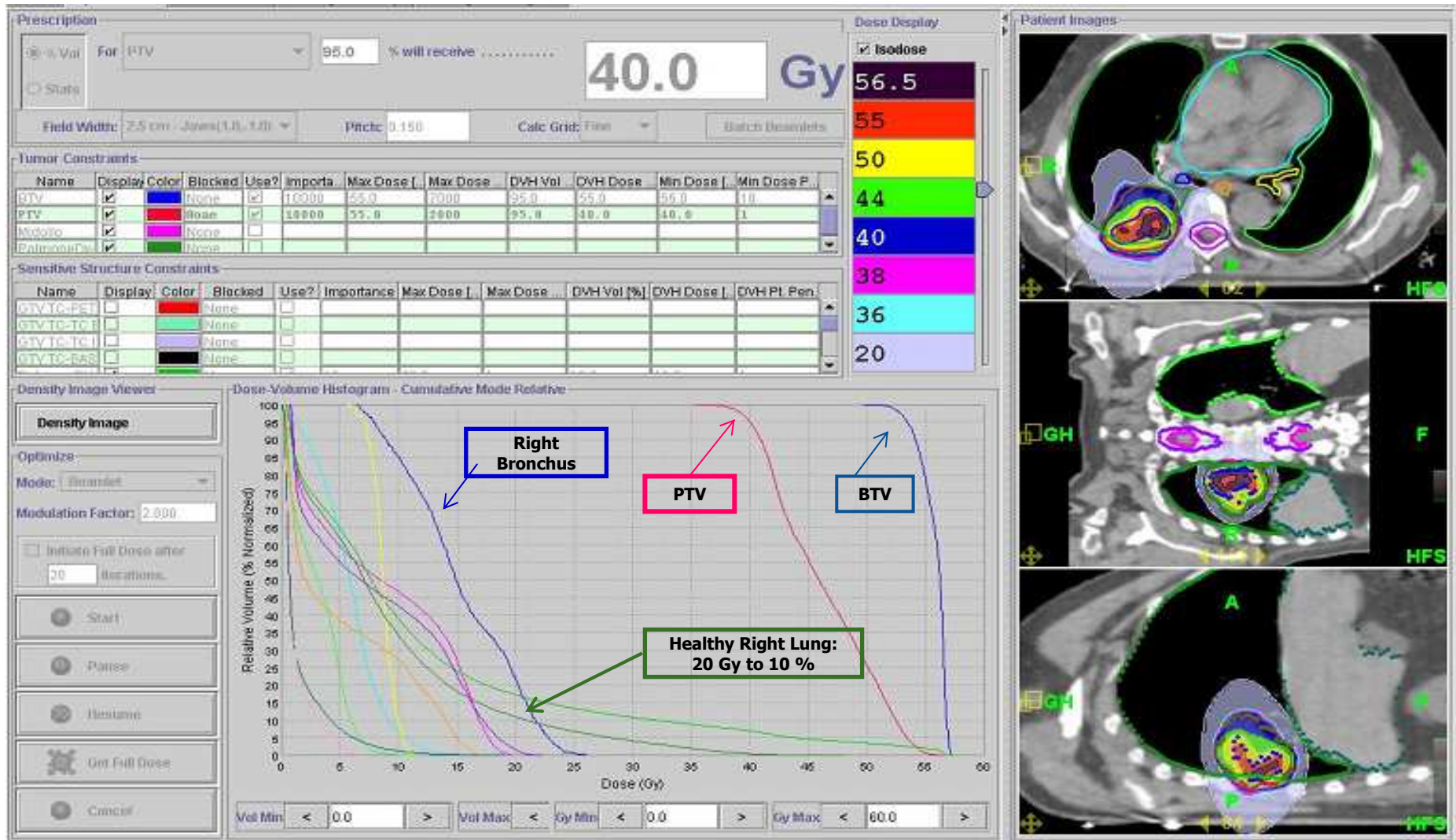
CRANIO SPINAL TODAY (20-36Gy)

Cranio Spinal - Clinical Tx

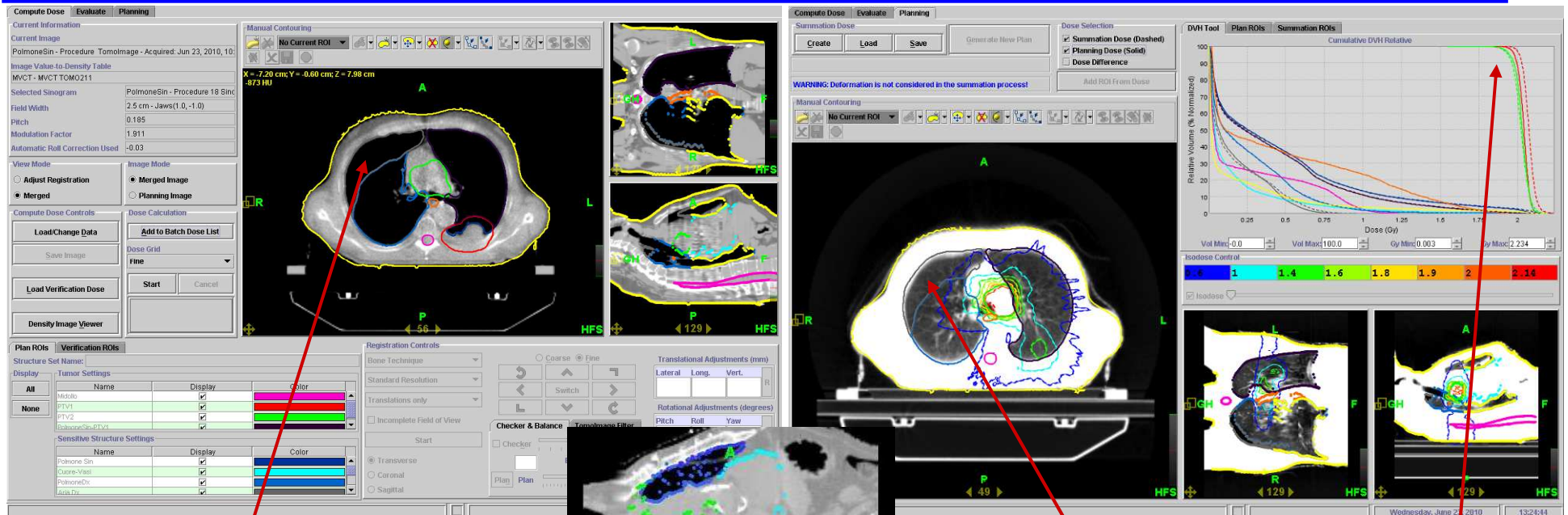
- Supine position
- Immobilization device (Mask)
- Target and Margin definition
- OAR objective
- Optimize verification time
- Optimize treatment time
- Analyze dosimetric accuracy
- **Treat patients**



SECONDARY LUNG CANCER RELAPSED AFTER RFA MULTIMODALITY IMAGE FUSION (SIB: BTV 55 Gy / 5 Fx - PTV 40 Gy / 5 Fx)



AIR CAVITY EFFECTS VS. ADAPTIVE RADIATION THERAPY VS. MOTION EFFECT



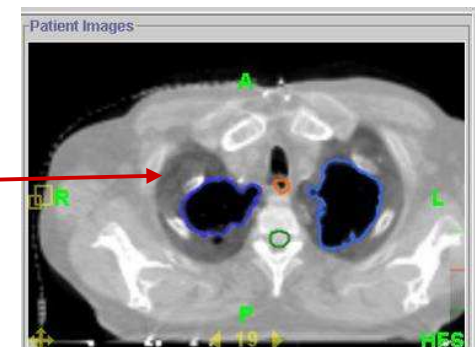
Air Cavity: Density equal 0 g/cm^3
 Can create problem to the calculation?

During the treatment cycle can change the anatomy
 Results?
 The previous plan can be different than the current delivery

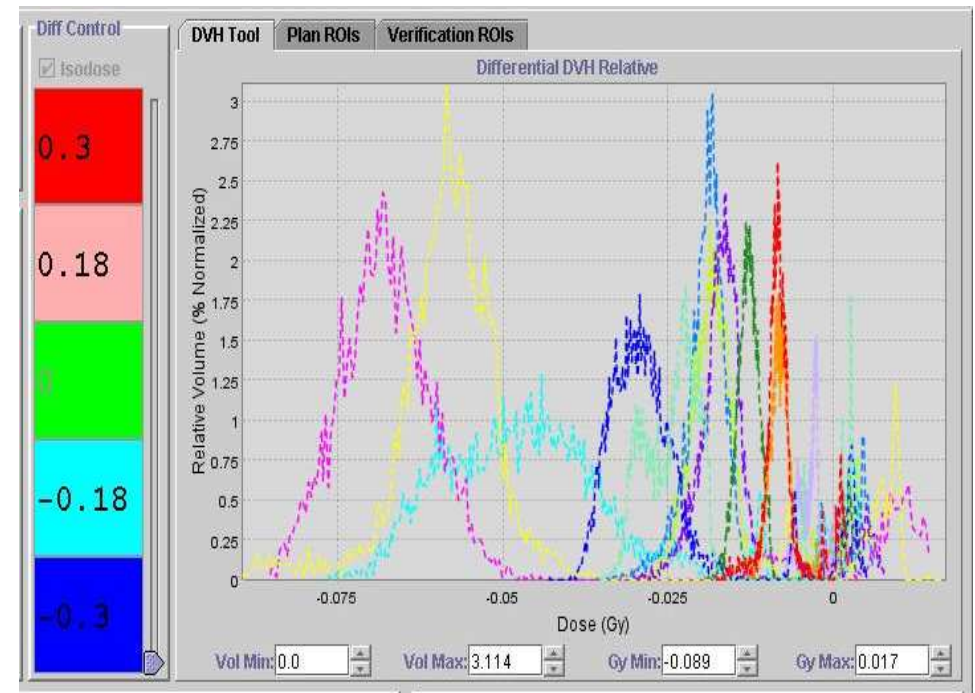
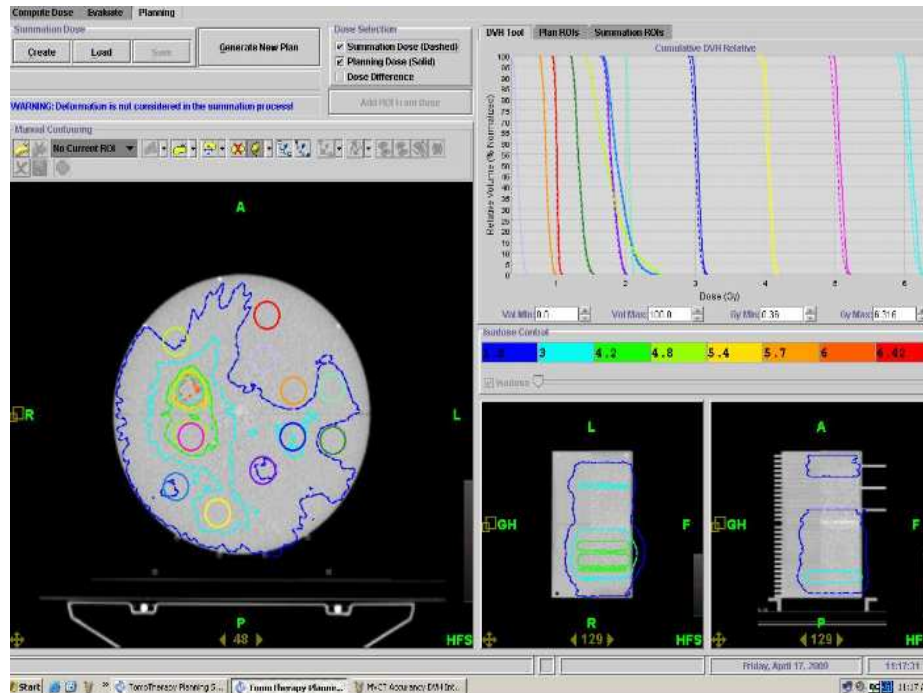
Using an Adaptive RT approach and a DVH analysis can show an idea of the current mistake and possible missing.

Be careful, could be not perfect!!!!

- Breathing cycle effects and artifact – Organ deformation
- MVCT density table modification due to the target degradation
- Fusion algorithm (mutual information) can smooth some effect due the voxel volume considered
- Some software trick of image concatenation



MVCT SUITABLE FOR ADAPTIVE RT : DOSIMETRIC EVALUATIONS



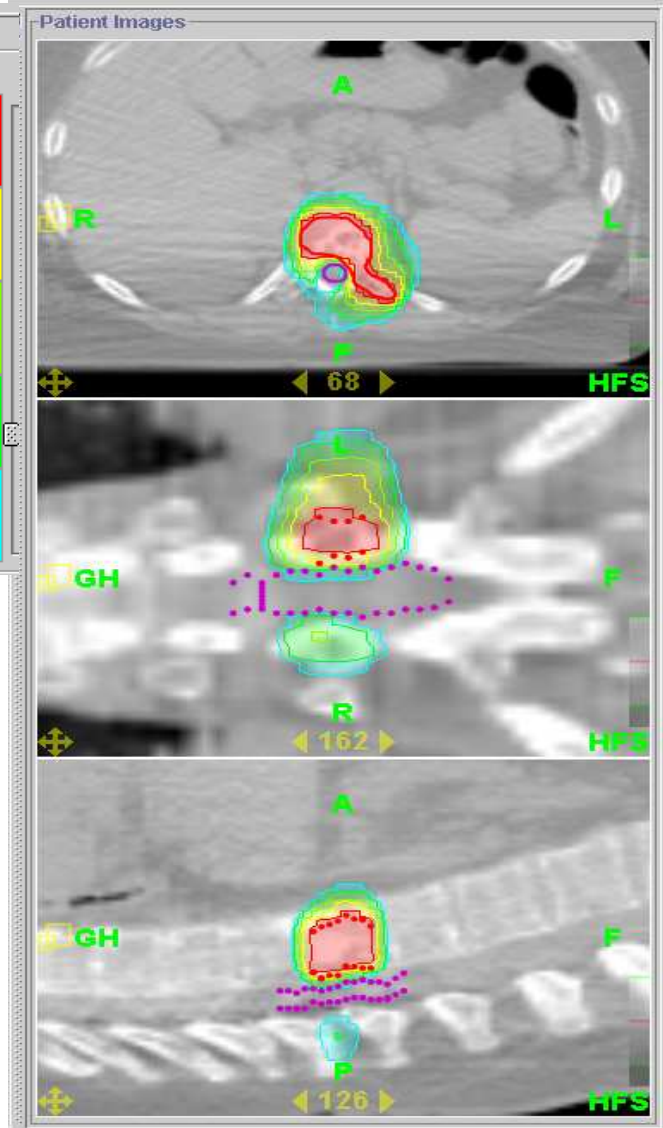
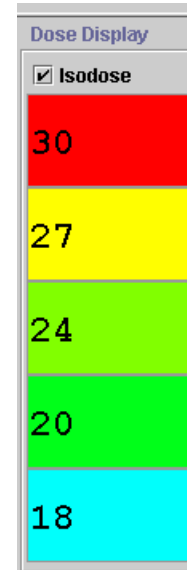
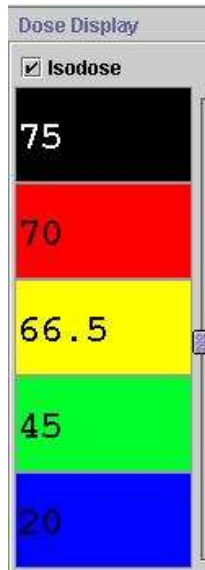
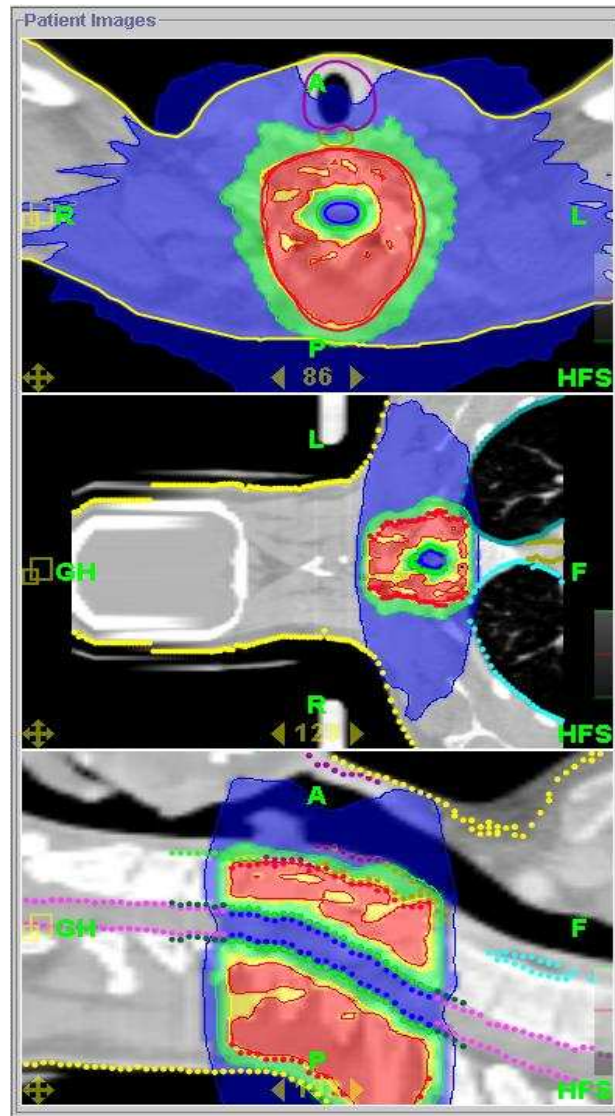
Result : difference of 0.08Gy (1%) for one fraction of 5Gy

The problem is the reliability and stability of the MVCT during the time...
The degradation of the target can change the data...
(UNDER INVESTIGATION)

SPINAL SARCOMA (PTV 70 Gy / 35 FX)

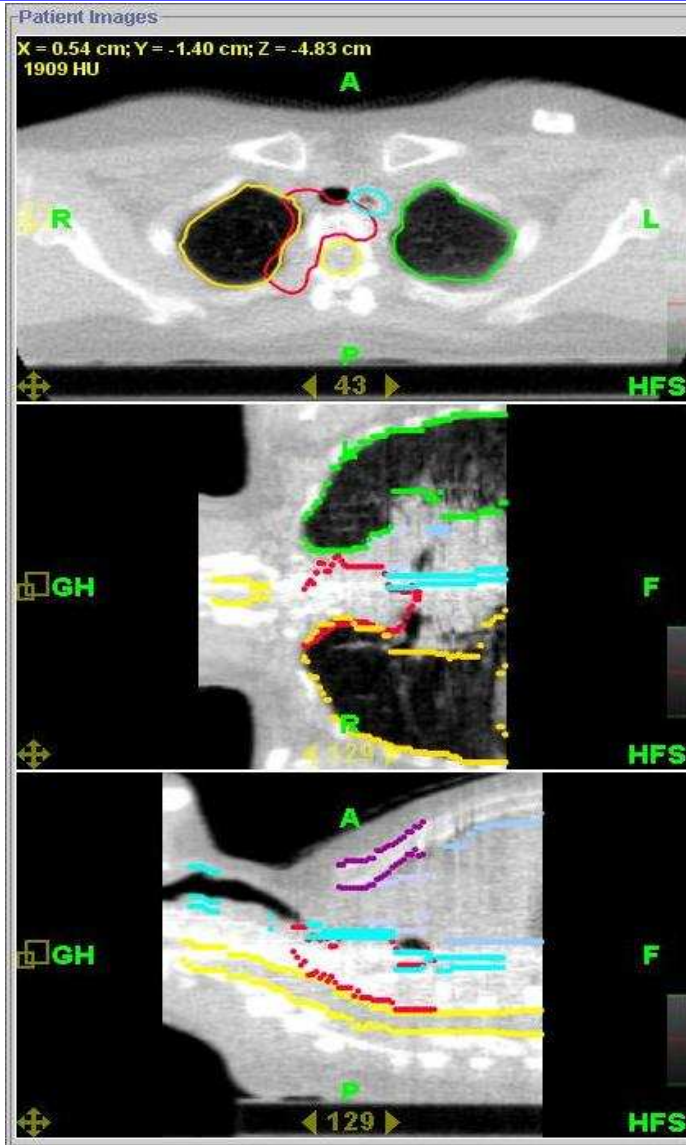
PALLIATIVE CASES

VERTEBRA (PTV 30Gy)



SPINAL METAL PROSTHESIS (Using MVCT)

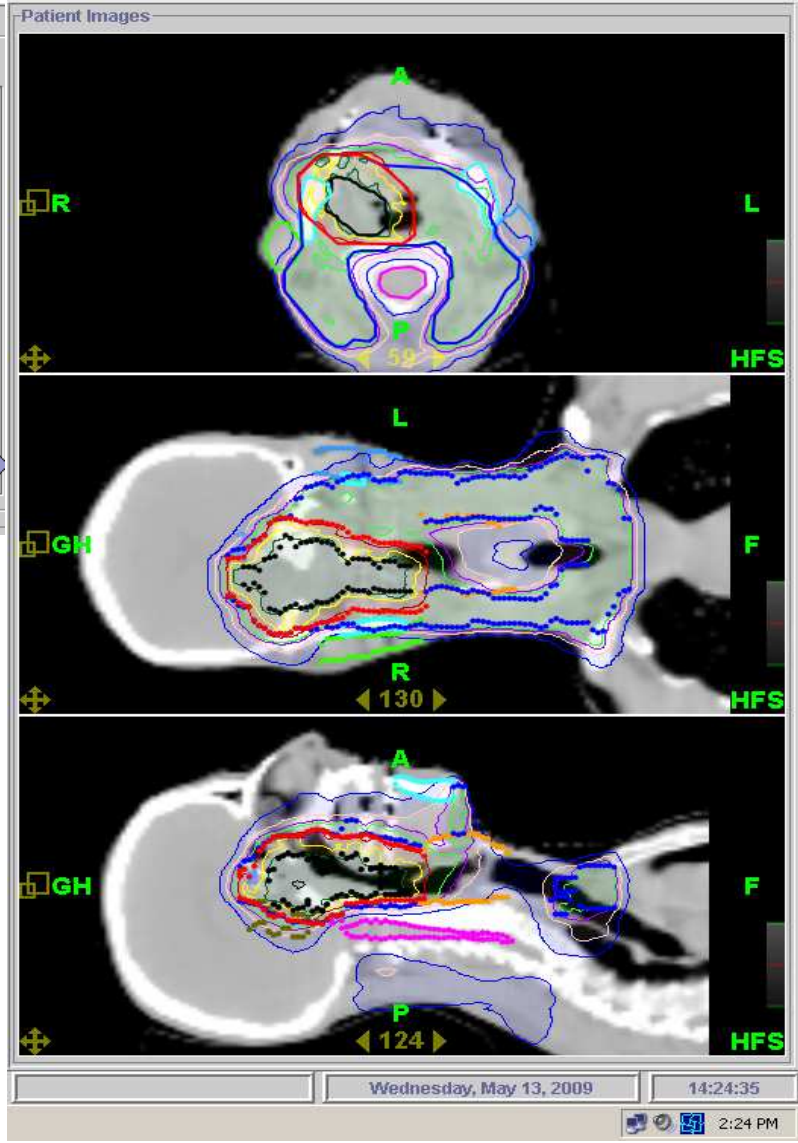
H&N in 30Fx (PTV1:70Gy - PTV2:64 Gy - PTV3:54 Gy)



Dose Display

Isodose

70.62
64
62.7
60
54
51
45
35



ABDOMINAL TREATMENT (PTV 22,5 GY / 15 FX)

Prescription

Vol For PTV 95.0 % will receive **22.5 Gy**

Stats

Field Width: 5.02 cm - Jaws(2.1, 2.1) Pitch: 0.213 Calc Grid: Normal Batch Beamlets

Tumor Constraints

Name	Display	Color	Blocked	Use?	Import...	Max Dose [Gy]	Max Dose Pe...	DVH Vol [%]	DVH Dose [Gy]	Min Dose [Gy]	Min Dose Pen
PTV	<input checked="" type="checkbox"/>	Red	None	<input checked="" type="checkbox"/>	20	22.5	300	95.0	22.5	22.5	300
Midollo	<input checked="" type="checkbox"/>	Green	None	<input type="checkbox"/>							

Sensitive Structure Constraints

Name	Display	Color	Blocked	Use?	Import...	Max Dose [Gy]	Max Dose Pe...	DVH Vol [%]	DVH Dose [Gy]	DVH Pt. Pen.
Intestino	<input checked="" type="checkbox"/>	Yellow	None	<input checked="" type="checkbox"/>	1	22.5	1	100.0	20.0	2
Milza	<input checked="" type="checkbox"/>	Orange	None	<input checked="" type="checkbox"/>	1	22.5	1	100.0	20.0	2
Cuore	<input checked="" type="checkbox"/>	Pink	None	<input checked="" type="checkbox"/>	1	22.5	1	40.0	20.0	3
CTV somma	<input type="checkbox"/>	Blue	None	<input type="checkbox"/>						

Density Image Viewer

Density Image

Optimize Mode: Beamlet Modulation Factor: 3.200

Initiate Full Dose after 20 iterations.

Start Pause Resume Get Full Dose Cancel

Dose Display

Isodose

24.75
 22.5
 21.375
 20.25
 18
 15.75

Patient Images

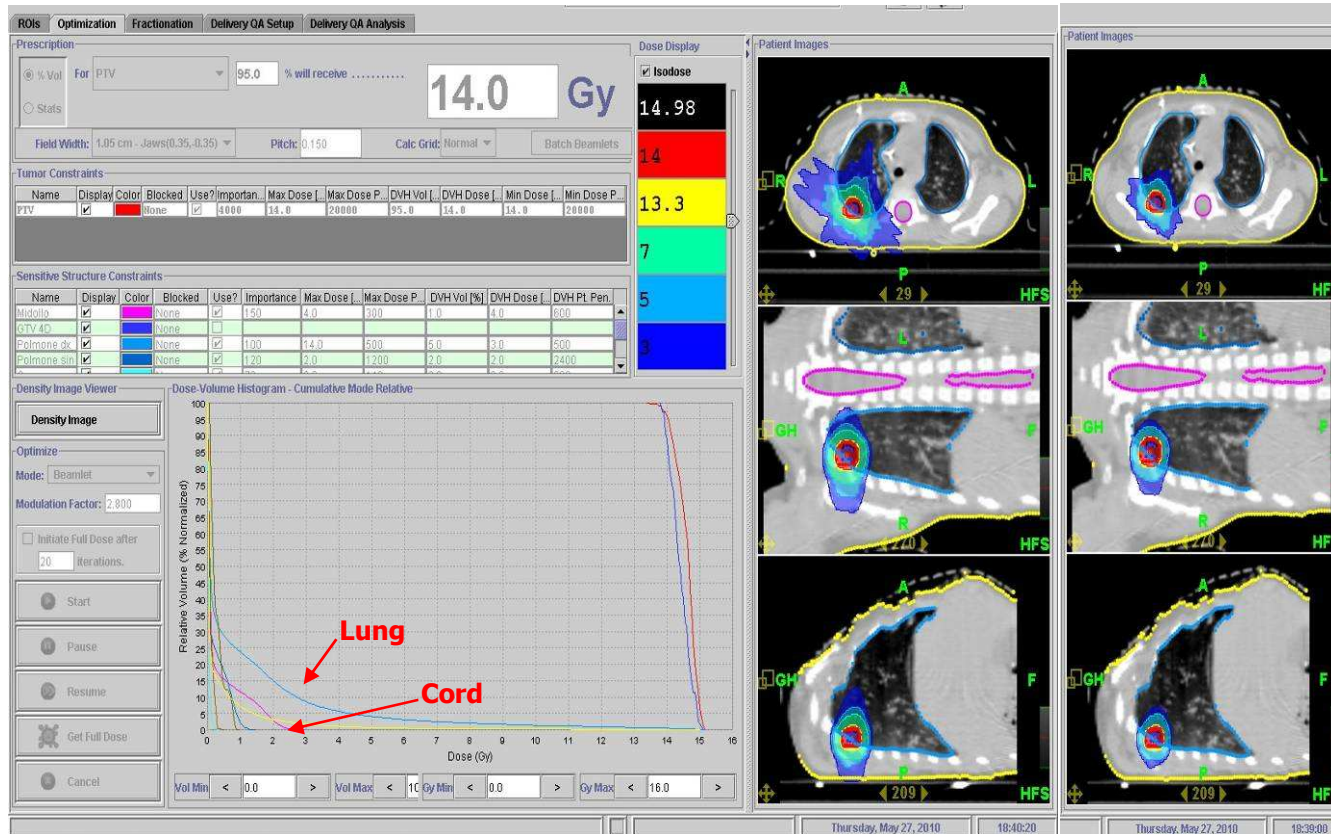
Dose-Volume Histogram - Cumulative Mode Relative

Relative Volume (% Normalized)

Dose (Gy)

Vol Min < 0.0 > Vol Max < 100.0 > Gy Min < 0.0 > Gy Max < 26.0 >

PAEDIATRIC TREATMENTS (14 Gy / 2 Fx) – 2 YEARS OLD REDUCE THE NUMBER OF ANESTHESIA



Breathing effect during 3DCRT and MicroMLC treatment

Tomotherapy advantages vs. MicroMLC or Cone systems

- No systems collision
- Low integral dose (3 Gy dose is showed)
- Concomitant anesthesia and patient monitoring very easy
- No dose at the contra lateral lung (trick during planning)
- Fast treatment (20minutes)
- Easy spare of the organ at risks

PANCREAS (50.4 Gy / 28 Fx)

ROIs Optimization Fractionation Delivery QA Setup Delivery QA Analysis

Fraction Count: 28

The plan has 28 fractions defined for a planned delivery of 50.4 Gy.
 98.0% of the PTV volume receives at least 50.4 Gy for the current plan.
 Modulation factor for this tomotherapy IMRT plan is 2.357

Unlock All Fractions

Fraction	Locked	Fraction Date	Fraction	Locked	Fraction Date
1	<input type="checkbox"/>	June 24, 2010	16	<input type="checkbox"/>	July 15, 2010
2	<input type="checkbox"/>	June 25, 2010	17	<input type="checkbox"/>	July 16, 2010
3	<input type="checkbox"/>	June 28, 2010	18	<input type="checkbox"/>	July 19, 2010
4	<input type="checkbox"/>	June 29, 2010	19	<input type="checkbox"/>	July 20, 2010
5	<input type="checkbox"/>	June 30, 2010	20	<input type="checkbox"/>	July 21, 2010
6	<input type="checkbox"/>	July 01, 2010	21	<input type="checkbox"/>	July 22, 2010
7	<input type="checkbox"/>	July 02, 2010	22	<input type="checkbox"/>	July 23, 2010
8	<input type="checkbox"/>	July 05, 2010	23	<input type="checkbox"/>	July 26, 2010
9	<input type="checkbox"/>	July 06, 2010	24	<input type="checkbox"/>	July 27, 2010
10	<input type="checkbox"/>	July 07, 2010	25	<input type="checkbox"/>	July 28, 2010
11	<input type="checkbox"/>	July 08, 2010	26	<input type="checkbox"/>	July 29, 2010
12	<input type="checkbox"/>	July 09, 2010	27	<input type="checkbox"/>	July 30, 2010
13	<input type="checkbox"/>	July 12, 2010	28	<input type="checkbox"/>	August 02, 2010
14	<input type="checkbox"/>	July 13, 2010			
15	<input type="checkbox"/>	July 14, 2010			

Dose Display: Isodose

53.928
 50.4
 47.88
 45.36
 40.32
 35.28
 25.2
 15.12

Finalize: Final Dose, Final Accept, Plan Report

Tumor Settings:

Name	Display	Color
Midollo	<input checked="" type="checkbox"/>	Magenta
PTV	<input checked="" type="checkbox"/>	Red
Rene Somn	<input checked="" type="checkbox"/>	Green

Sensitive Structure Settings:

Name	Display	Color
Polmone s	<input checked="" type="checkbox"/>	Blue
Polmone d	<input checked="" type="checkbox"/>	Blue
Rene sx	<input checked="" type="checkbox"/>	Magenta
Rene dx	<input checked="" type="checkbox"/>	Magenta
CTV	<input checked="" type="checkbox"/>	Blue
Fegato	<input checked="" type="checkbox"/>	Orange
Cuore	<input checked="" type="checkbox"/>	Cyan
Body	<input checked="" type="checkbox"/>	Yellow
MidExp	<input type="checkbox"/>	Green
Rino	<input type="checkbox"/>	Red

Patient Images

Dose-Volume Histogram - Cumulative Mode Relative

Vol Min < 0.0 > Gy Min < 0.0 > Gy Max < 55.0 >

RECURRENT MENINGIOMA - RS 45 Gy /3 Fx – BRAINSTEM : 3 Gy (PREVIOUS TREATMENT 54 Gy – BRAINSTEM 54 Gy)

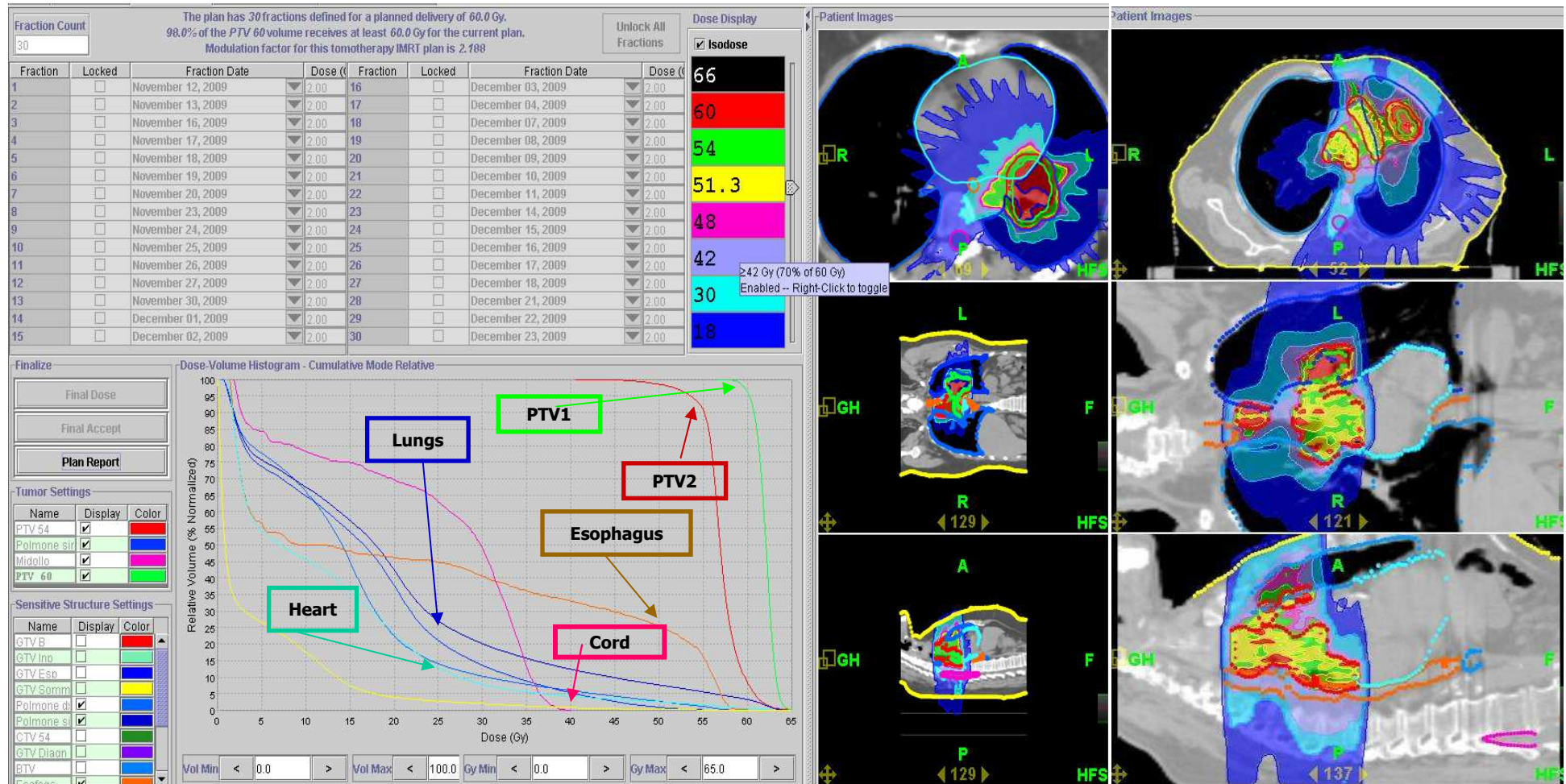
The screenshot displays a radiotherapy planning software interface with the following sections:

- ROIs Optimization Fractionation Delivery QA Setup Delivery QA Analysis**
- Prescription:** % Vol For PTV 96.0 % will receive **45.0 Gy**
- Dose Display:** Isodose 48.15, 45, 42.75, 40, 35, 30, 20, 10
- Tumor Constraints Table:**

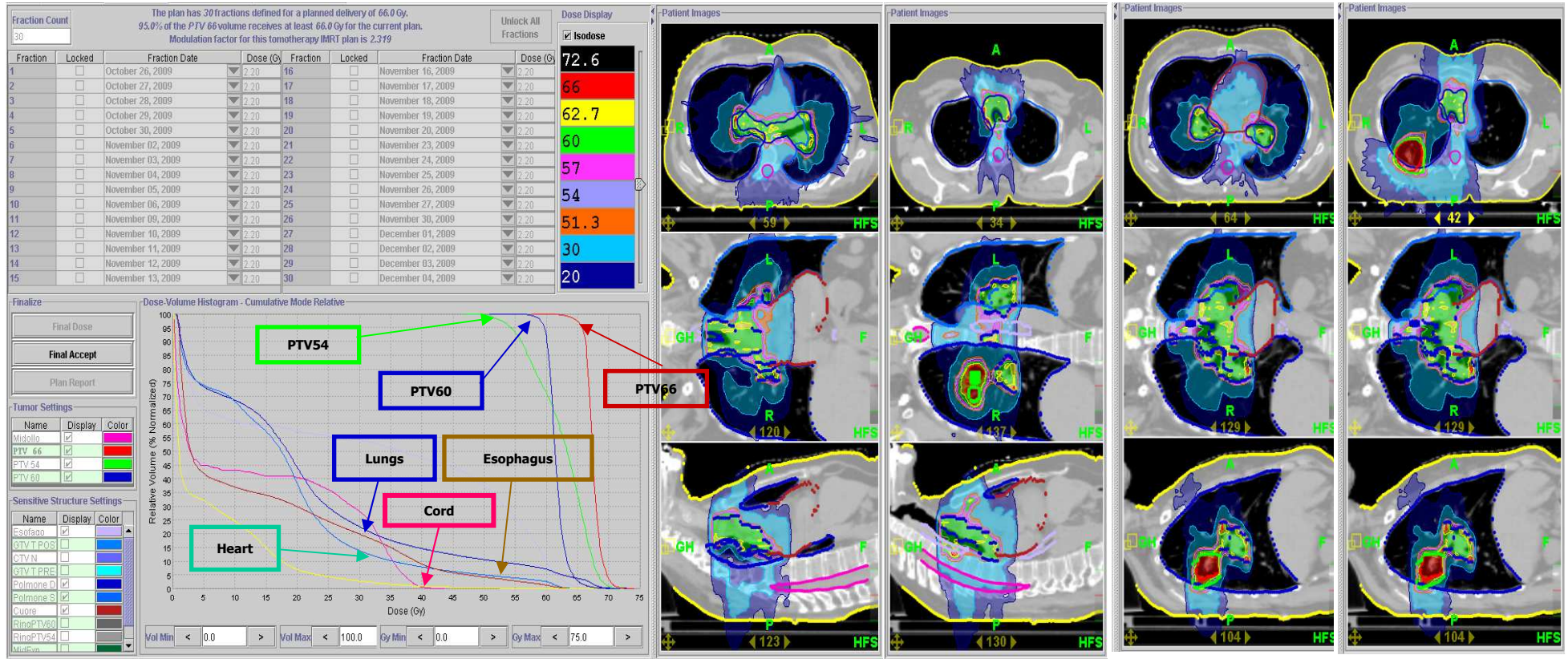
Name	Display	Color	Blocked	Use?	Importa...	Max Dose [...]	Max Dose ...	DVH Vol [...]	DVH Dose [...]	Min Dose [...]	Min Dose P...
PTV	<input checked="" type="checkbox"/>	Red	None	<input checked="" type="checkbox"/>	50	45.0	50	96.0	45.0	45.0	50
- Sensitive Structure Constraints Table:**

Name	Display	Color	Blocked	Use?	Importance	Max Dose [...]	Max Dose ...	DVH Vol [%]	DVH Dose [...]	DVH Pt. Pen.
GTV	<input checked="" type="checkbox"/>	Blue	None	<input checked="" type="checkbox"/>						
Ponte	<input checked="" type="checkbox"/>	None	None	<input checked="" type="checkbox"/>	1.5	4.0	30	1.0	3.0	30
Occhio dx	<input checked="" type="checkbox"/>	Blue	None	<input checked="" type="checkbox"/>	5	2.0	10	10.0	1.0	3
Occhio sin	<input checked="" type="checkbox"/>	Blue	None	<input checked="" type="checkbox"/>	5	2.0	10	10.0	1.0	3
- Density Image Viewer:** Density Image, Optimize Mode: Beamlet, Modulation Factor: 2.000, Start, Pause, Resume, Get Full Dose, Cancel
- Dose-Volume Histogram - Cumulative Mode Relative:** Graph showing Relative Volume (% Normalized) vs Dose (Gy). Key points: Brainstem (purple box), Kidney (green box), PTV (red box), Cord (pink box).
- Patient Images:** Axial and sagittal CT scans with isodose lines and target/organ contours.

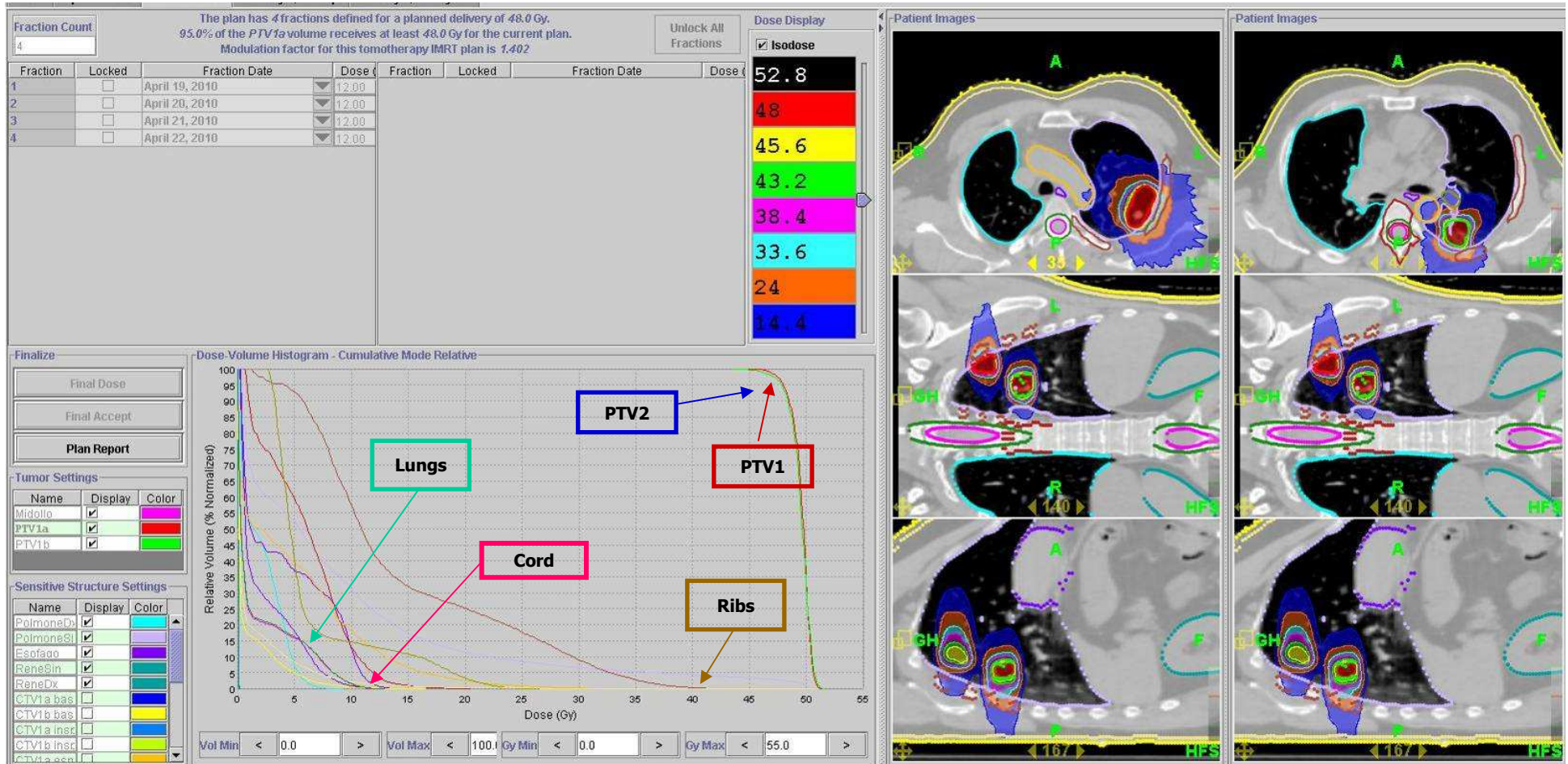
LUNG LESION (PTV1: 60 Gy / 30Fx – PTV2: 54Gy / 30 Fx)



LUNG LESION + BILATERAL ILA + MEDIASTINUM (PTV66 Gy /33 Fx – PTV60 Gy / 33 Fx – PTV54 Gy /33Fx)



SBRT MULTIPLE LUNG LESIONS (48 GY / 4FX)



PELVIS
(PTV1 63Gy – PTV2: 50.4Gy / 28 Fx)

Prostate
(PTV1 54Gy – PTV2: 70Gy / 28 Fx)

Prescription

Vol For PTV 63 95.0 % will receive **63.0 Gy**
 Stats

Field Width: 2.5 cm - Jaws(1.0,1.0) Pitch: 0.287 Calc Grid: Normal Batch Beamlets

Tumor Constraints

Name	Display	Color	Blocked	Use?	Importan...	Max Dose [...]	Max Dose P...	DVH Vol [...]	DVH Dose [...]	Min Dose [...]	Min Dose P...
PTV 50.4	<input checked="" type="checkbox"/>		None	<input checked="" type="checkbox"/>	300	50.4	10	95.0	50.4	50.4	10
PTV 63	<input checked="" type="checkbox"/>		None	<input checked="" type="checkbox"/>	700	63.0	40	95.0	63.0	63.0	10

Sensitive Structure Constraints

Name	Display	Color	Blocked	Use?	Importance	Max Dose [...]	Max Dose P...	DVH Vol [%]	DVH Dose [...]	DVH PL Pen.
CTV1	<input type="checkbox"/>		None	<input type="checkbox"/>						
femore dx	<input checked="" type="checkbox"/>		None	<input checked="" type="checkbox"/>	3	45.0	3	1.0	44.0	3
femore sx	<input checked="" type="checkbox"/>		None	<input checked="" type="checkbox"/>	3	45.0	3	1.0	44.0	3
retto	<input checked="" type="checkbox"/>		None	<input checked="" type="checkbox"/>	30	62.0	10	30.0	45.0	30

Density Image Viewer

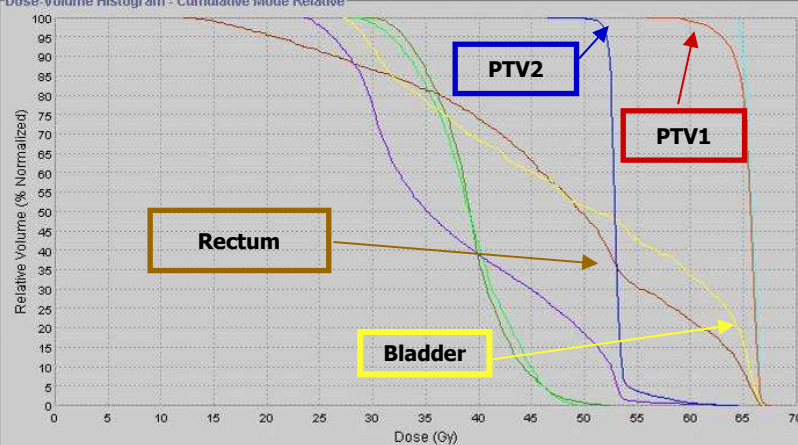
Density Image

Optimize Mode: Beamlet Modulation Factor: 2.000

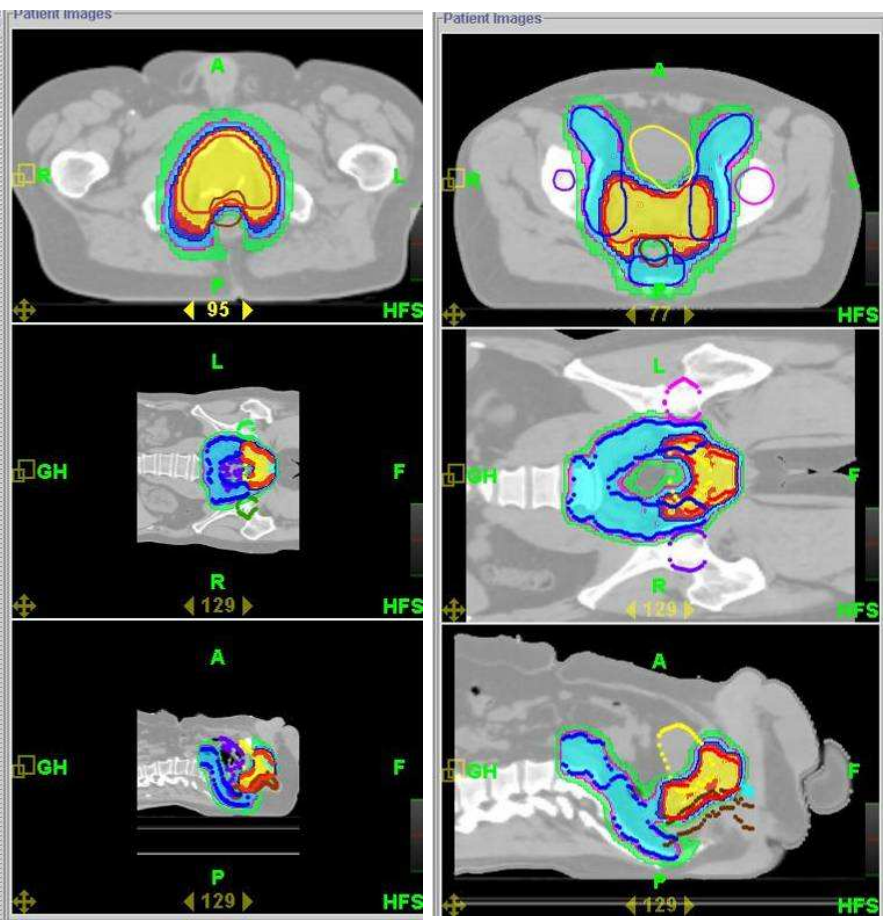
Initiate Full Dose after 20 iterations.

Start Pause Resume Get Full Dose Cancel

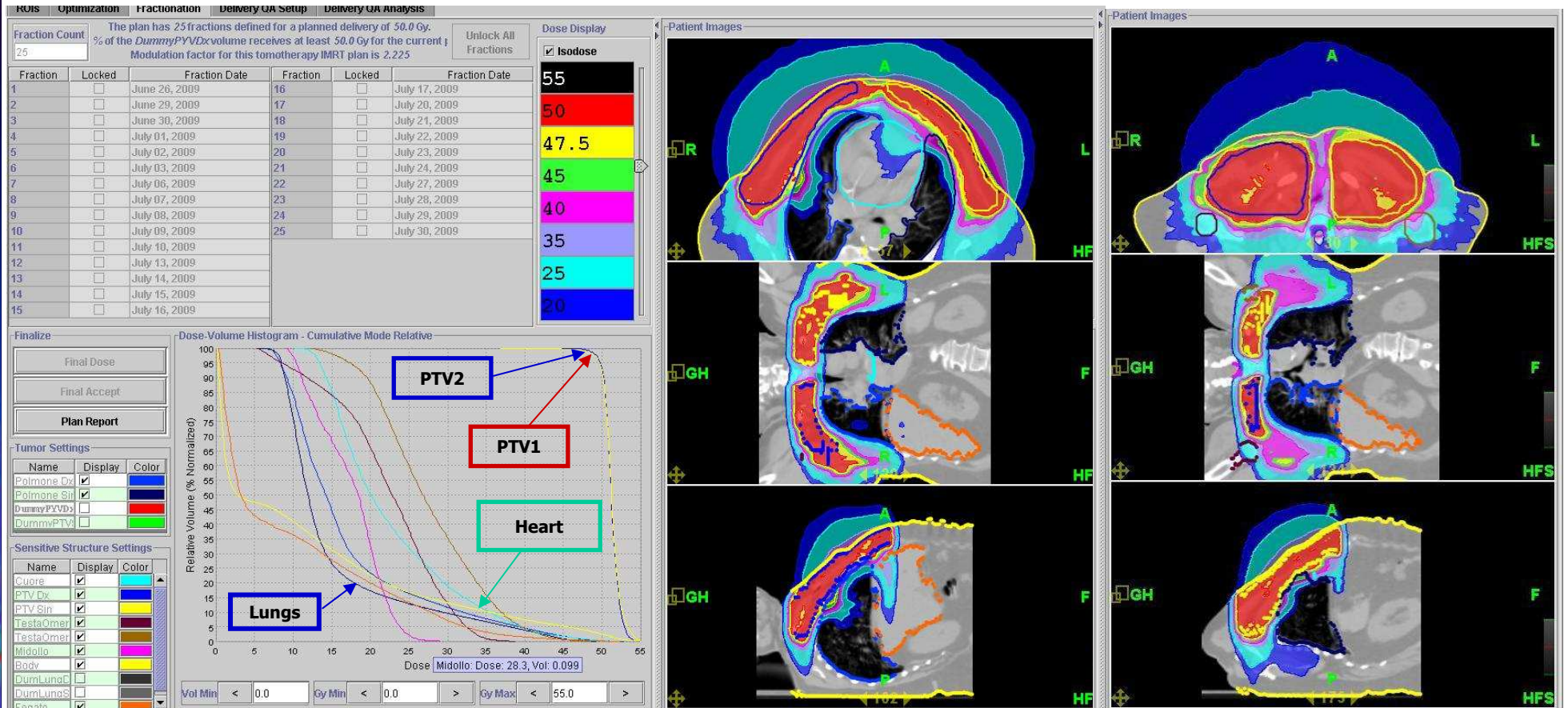
Dose-Volume Histogram - Cumulative Mode Relative



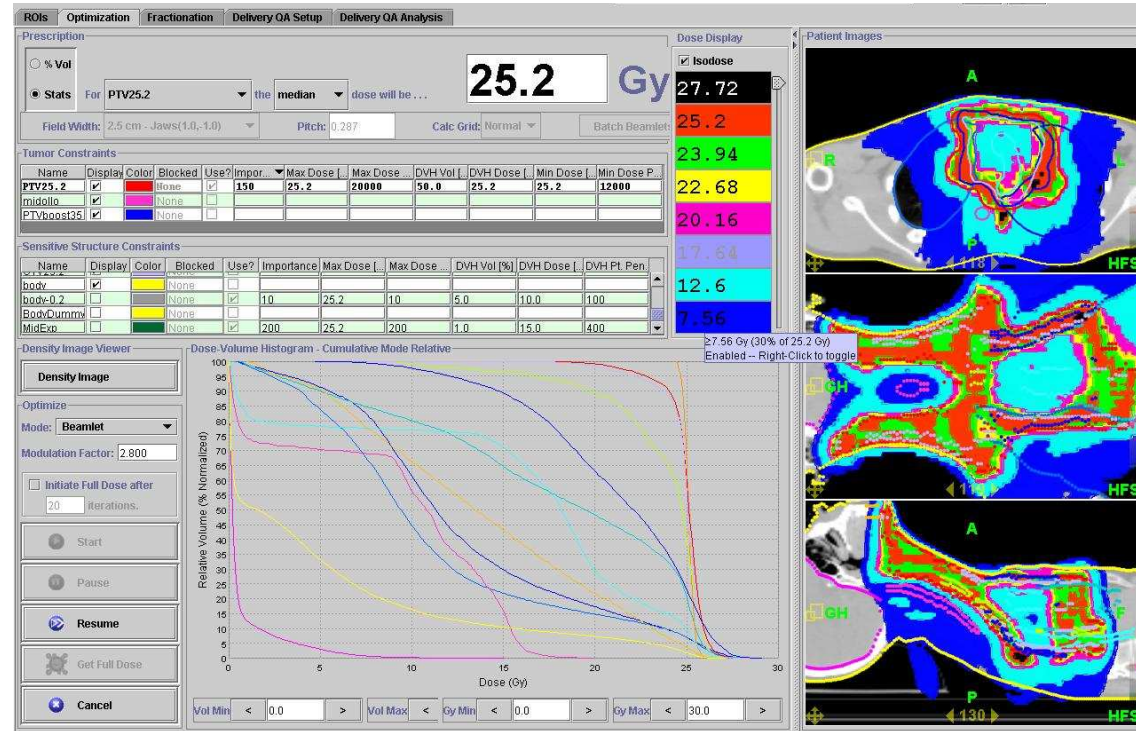
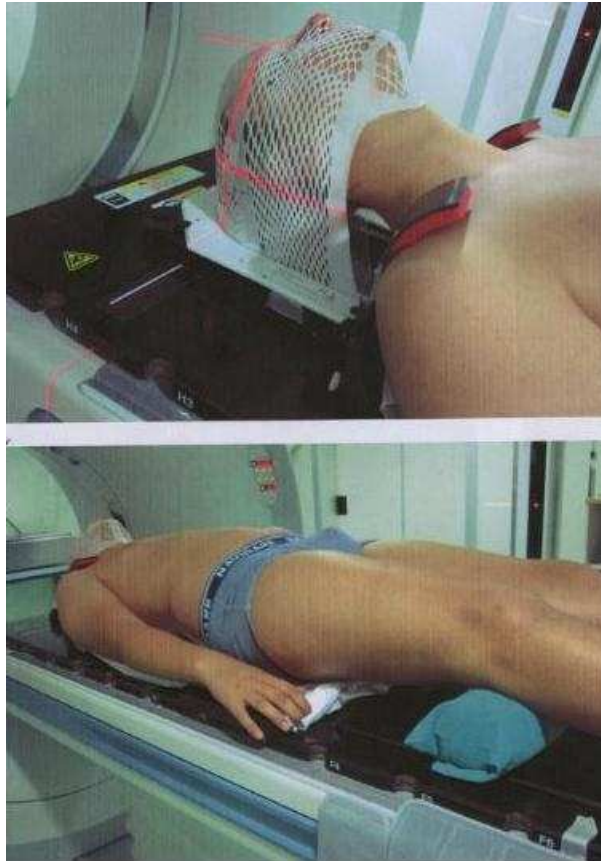
Vol Min < 0.0 > Vol Max < 10 Gy Min < 0.0 > Gy Max < 70.0 >



BILATERAL CHEST WALL + SUVRACLAVEAR (50 Gy / 25 Fx)



BAD SETUP IMMOBILIZATION – BAD PLAN APPROACH



Bad overlap priority of the structures consideration can create unexpected error during treatment and DVH could not show this error

Tomotherapy use a rotational delivery treatment, everything must be where is suppose to be during the planning

- Arms effect on the attenuation and improper dose at soft tissue
- Thorax bad fixation and breathing influences
- Leg and longitudinal alignment (MVCT correction could be complicate between upper and lower movement)
- Shoulder movement during the treatment or day by day positioning

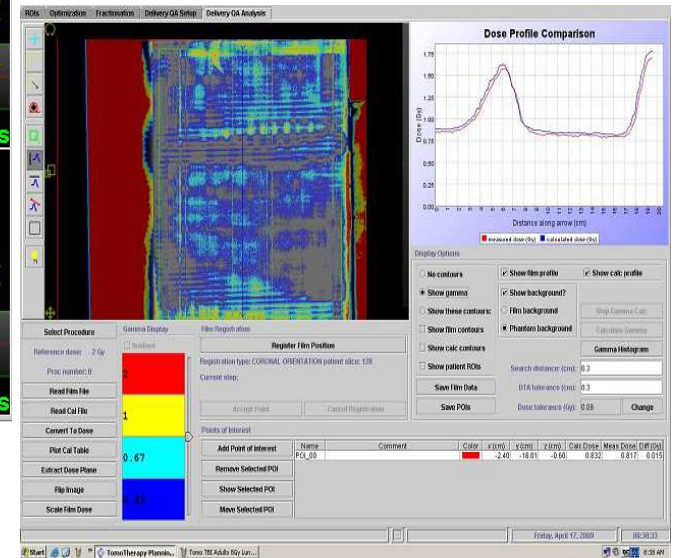
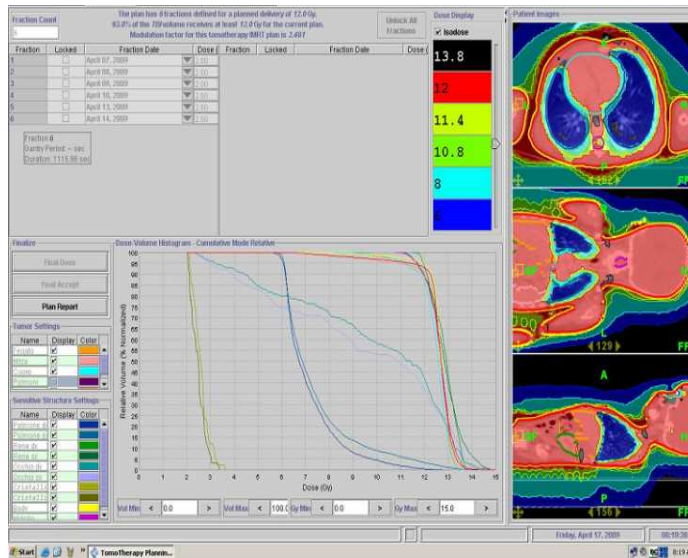
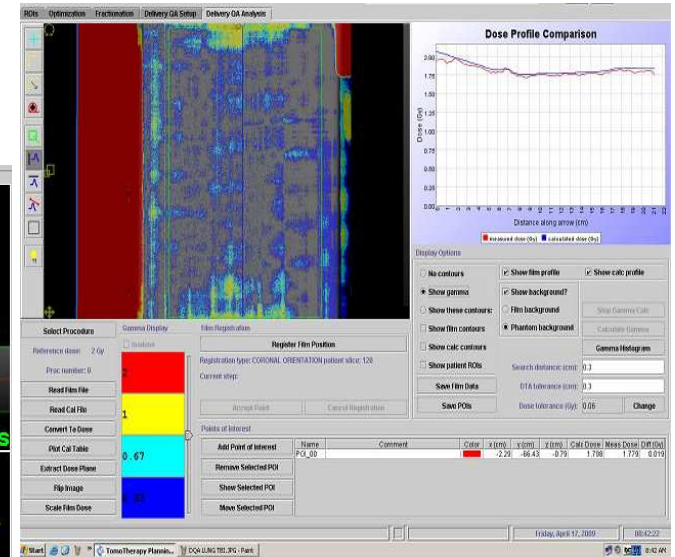
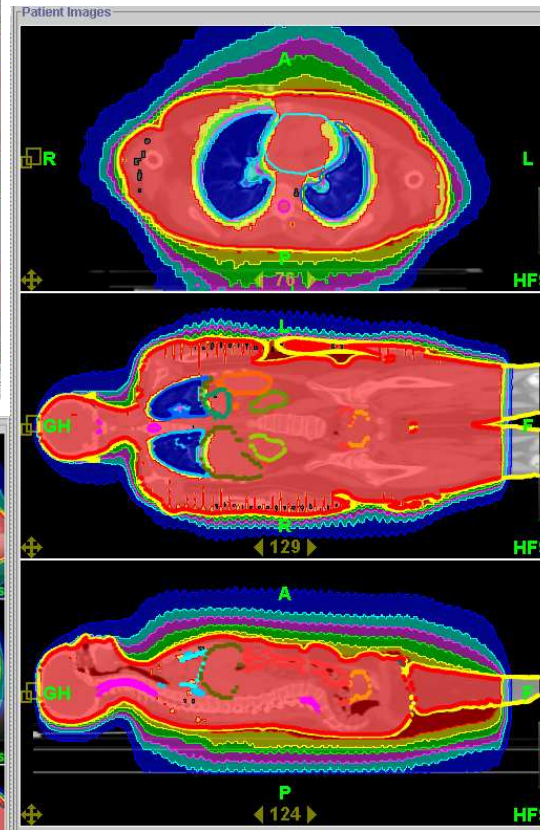
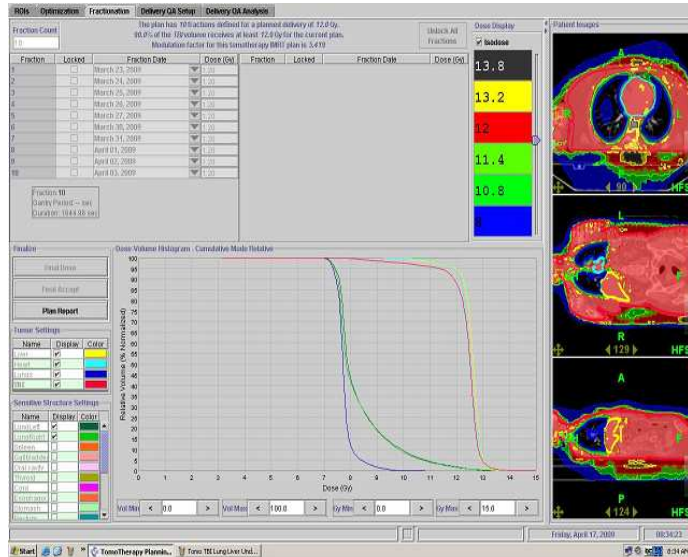
JUST FOR TRAINING !!! NOT REAL CASES

National Research and Collaboration (Project N°5 : Program PIO V)

Evolution of the Image Guided Radiation Therapy (IGRT) using Tomotherapy: feasibility and efficacy of Adaptive Radiation Therapy Techniques (ART), Hypo-Fractionation (HF), Target Biological Definition (BTV) and Total Body Irradiation (TTBI)

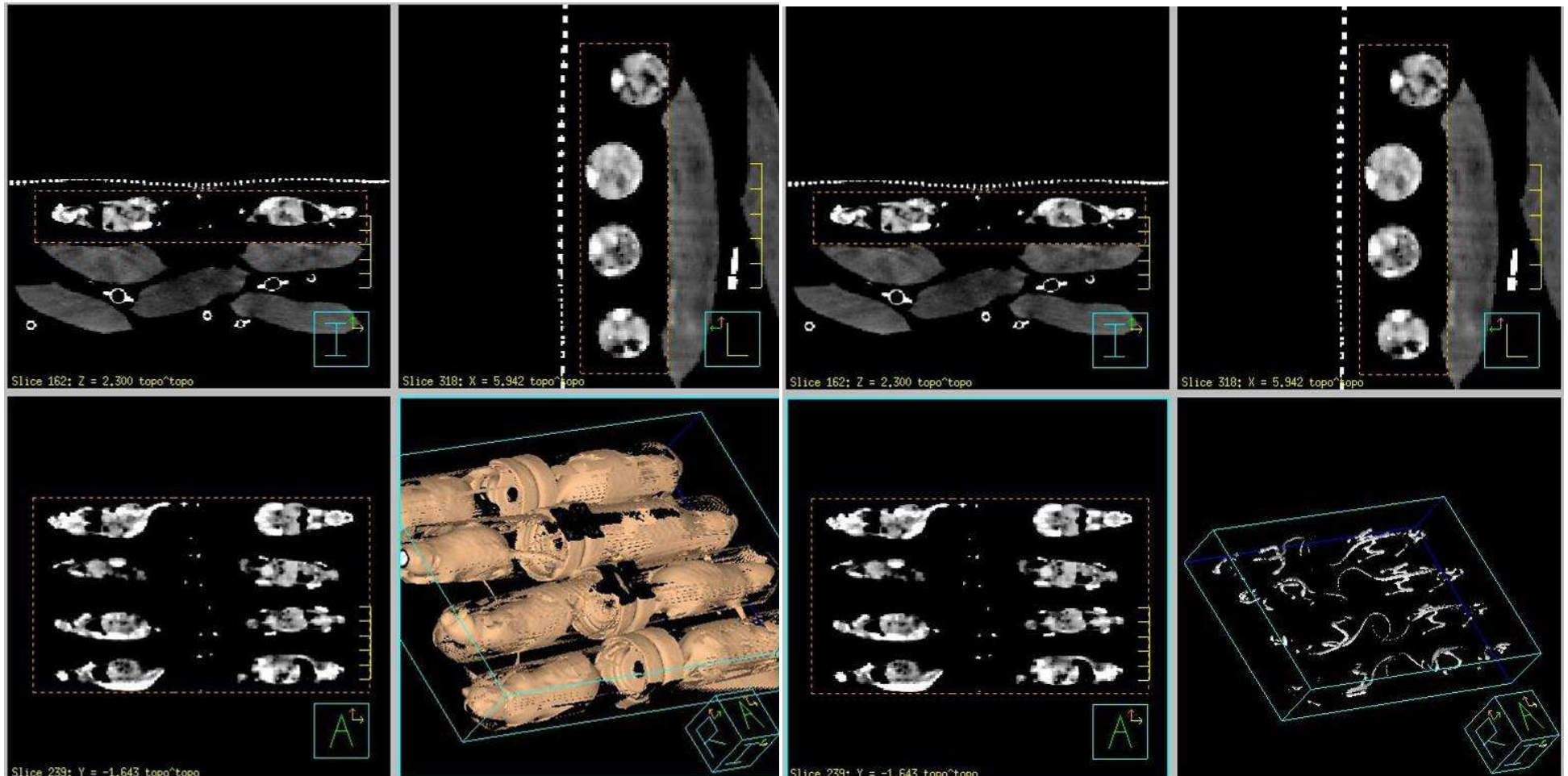
- MAIN RESEARCH CENTER
 - IRCCS – Centro di Riferimento Oncologico di Aviano (1)
- MULTI-CENTER COLLABORATION:
 - IRCCS – Ospedale S. Raffaele di Milano (2)
 - Regione Emilia Romagna - Arcispedale S. Maria Nuova di Reggio Emilia (3)
 - Regione Emilia Romagna - Azienda Ospedaliero Universitaria Policlinico di Modena (4)
- Objective
 1. Efficacy, efficiency and clinical evaluation of Adaptive Radiation Therapy system using multiple national health institutions, where Tomotherapy units are installed
 2. Prostate hypo-fractionated techniques evaluation to reduce the treatment time and assessment of dose escalation program to reduce the dose per fraction for adjuvant treatments after surgery. Local – Regional control and toxicity evaluation.
 3. Evaluation and definition of multi-modal imaging techniques for radiotherapy biological target definition (BTV). Clinical application and dose distribution optimization using physics and radio-biological parameter to improve clinical treatment efficacy
 4. **Clinical and dosimetric evaluation of Total Body Irradiation using Tomotherapy. Treatment and transplant procedure, adequacy and safety evaluations using Tomotherapy. Problem solving, efficacy and efficiency for human and paediatric treatments.**

RESEARCH RESULTS: TOTAL BODY IRRADIATION USING TOMOTHERY



In memory of Marco Corni (2008)

TBI RESEARCH: HIGH DOSERATE EFFECT IN MICE (TOMOTHERAPY 880-900cGy/min) (STUDY UNDER DEFINITION)

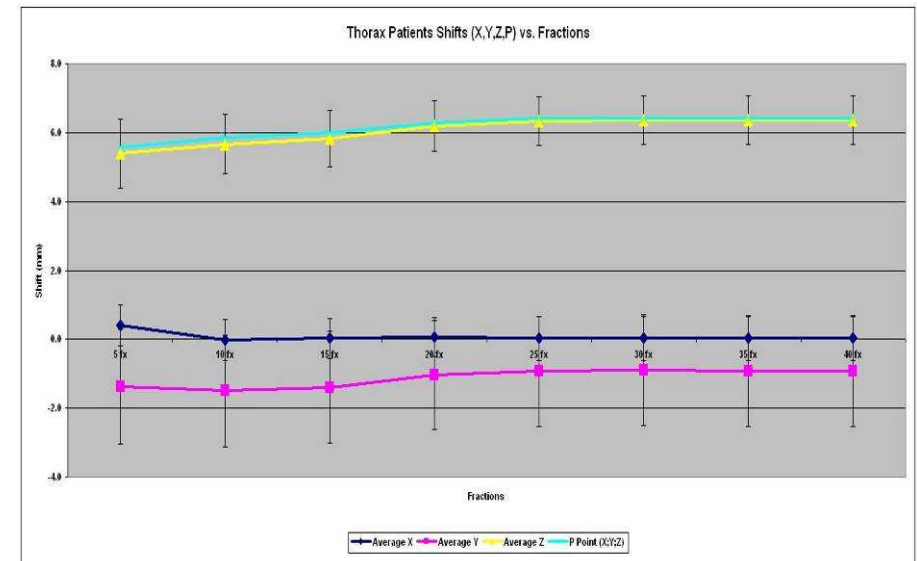
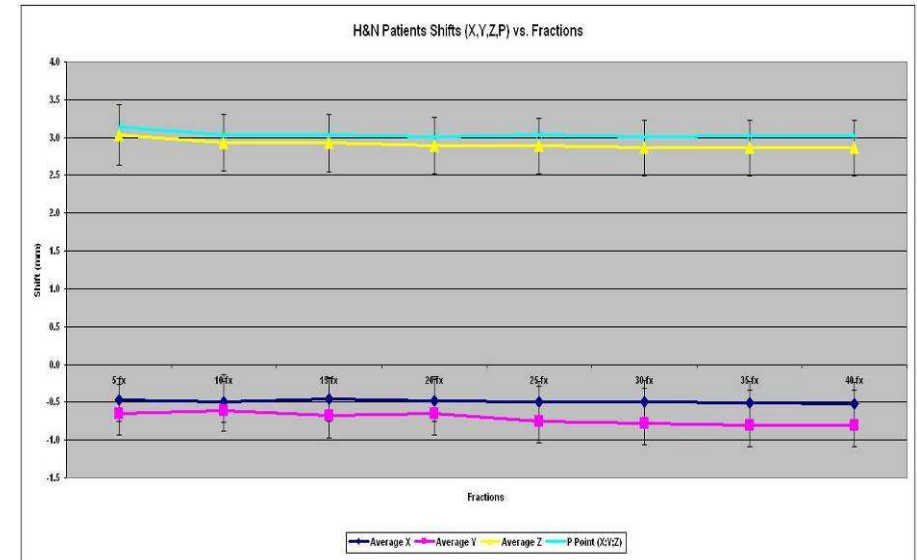
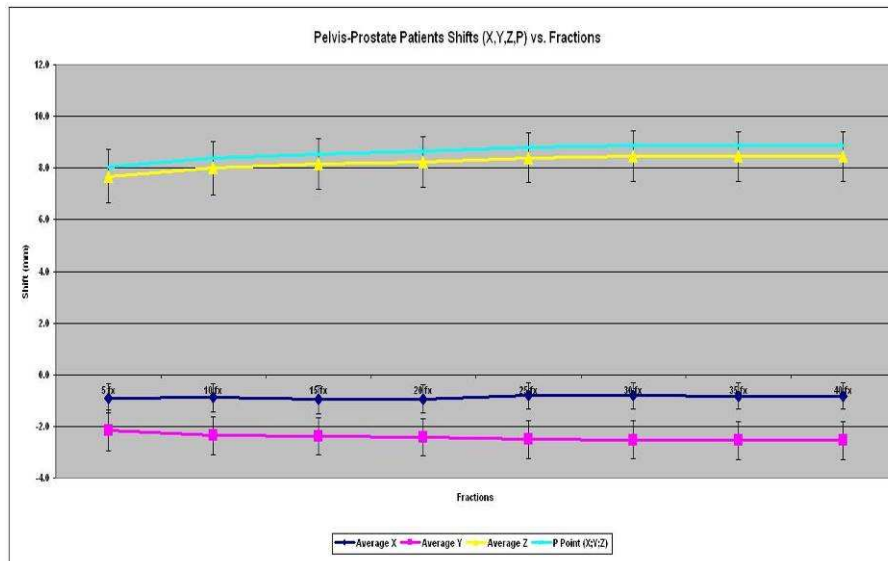


Idea by G.Guidi, F.Bertoni 2008, 2009, 2010

IMMOBILIZATION SYSTEM AND SET-UP ERRORS

Our data analysis shows that:

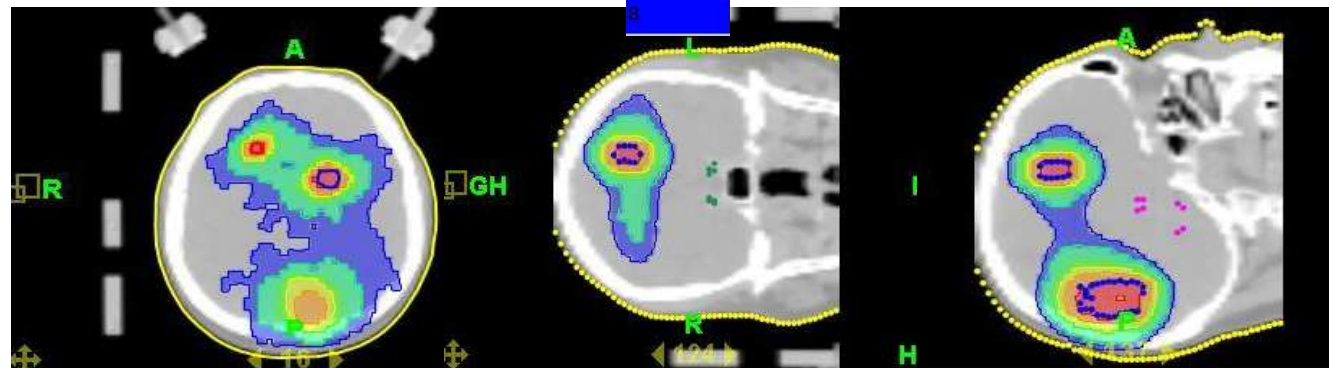
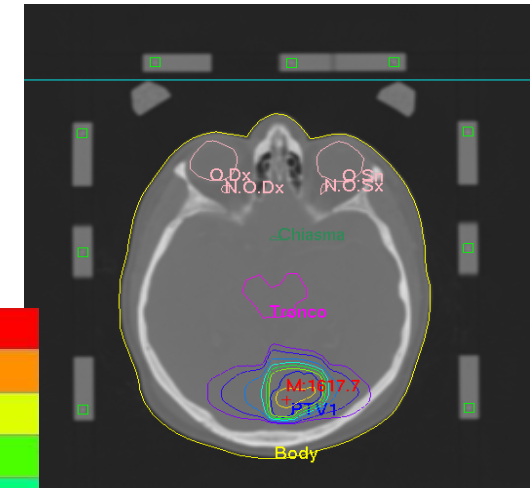
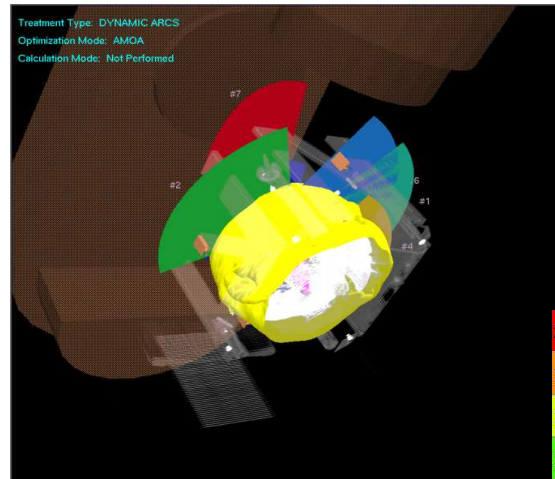
- Immobilization systems are adequate:
 - 3-fixing point thermoplastic masks for brain treatments (no invasive devices)
 - 5-fixing point masks with shoulder immobilization for head & Neck treatments
 - Thermoplastic masks with abdominal compression for thorax & abdomen treatments
- Reduced margins of CTV-PTV may be proposed with very low risk of geographic missing:
 - < 3 mm for brain
 - < 5 mm for head & neck
 - < 10 mm for thoracic & abdominal
- Senseless reduction of the margin could be very dangerous for the future outcomes of the patients



MANAGEMENT AND OPTIMIZATION HOW CAN I SAVE TIME (RADIOSURGERY)



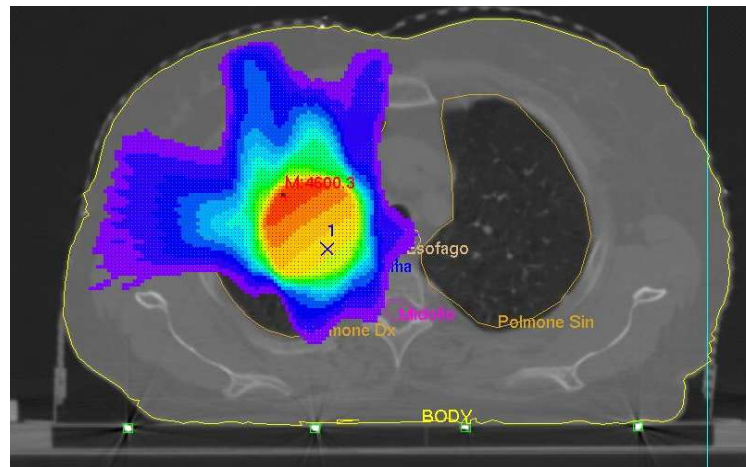
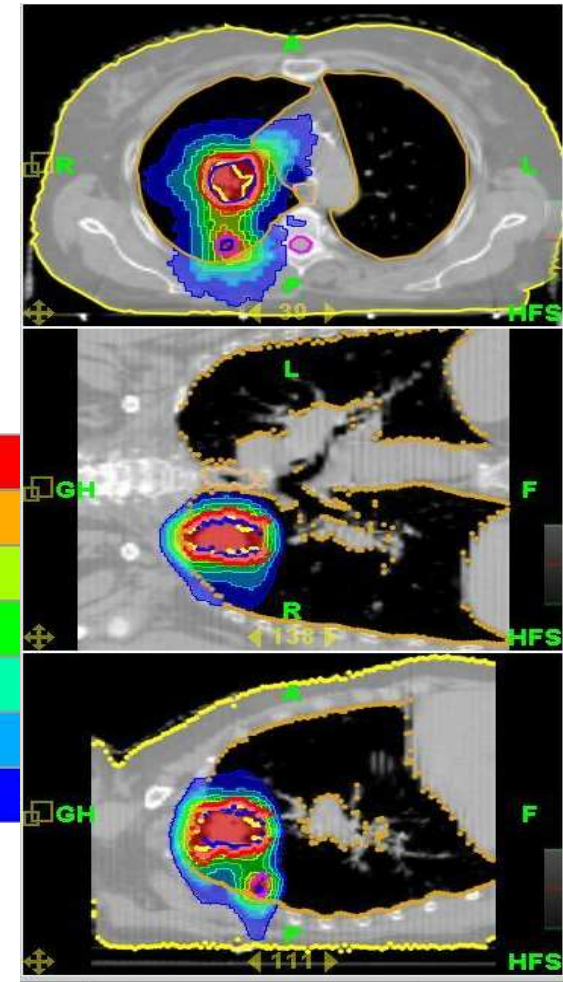
adapted from A. T. Villavicencio,
Duke University Medical Center



Equivalence???

**2 Radiosurgery using Tomotherapy = Same LINAC Occupation Time = 40 minutes at the LINAC available for 3DCRT = 4 Patients?
6 Patients (2 RS+4 pts. 3DCRT) treated at the center vs. 2 RS using 2 LINACs during the same time**

MANAGEMENT AND OPTIMIZATION HOW CAN I SAVE TIME (STEREOTACTIC BODY RADIATION THERAPY)



Equivalence???

**2 SBRT using Tomotherapy = Same LINAC Occupation Time = 50 minutes at the LINAC available for 3DCRT = 5 Patients?
7 Patients (2 SBRT+5 pts. 3DCRT) treated at the center vs. 2 SBRT using 2 LINACs during the same time**

MACHINE TIME MANAGEMENT

Site	Room Time			MVCT Time			Beam-On Time		
	Average	Min	Max	Average	Min	Max	Average	Min	Max
H-N	26,2	13	53	3,2	1,4	6,7	8	3,4	14
Thorax	35	23	50	3,5	2,5	6,2	11	7,6	15,6
Prostate	23	13	40	2,3	1,3	5,3	8,2	3,2	14,8
Global Average: 25,6 ± 8,7 minutes									

PHILOSOPHY OF THE CLINICAL AND TIME MANAGEMENT

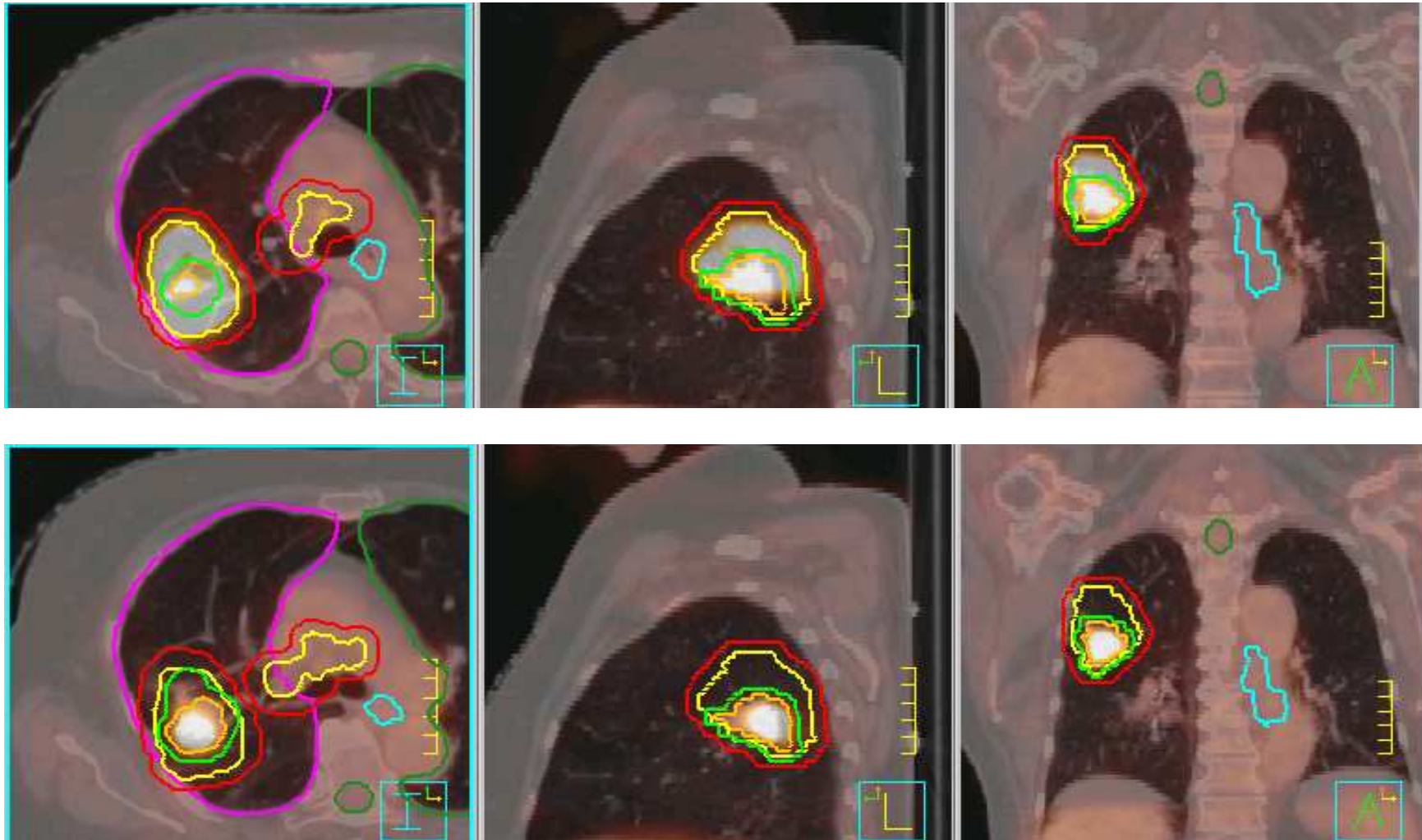
- Complex cases treated at the Tomotherapy Unit.....**
-Treatment time is not a must...**
- ...Room time occupation is not a must....**
- ...Plan must cover the clinical requirements....**
- ... with Tomo I have to obtain something otherwise complicate at the LINACs**

By G.Guidi, F.Bertoni 2008

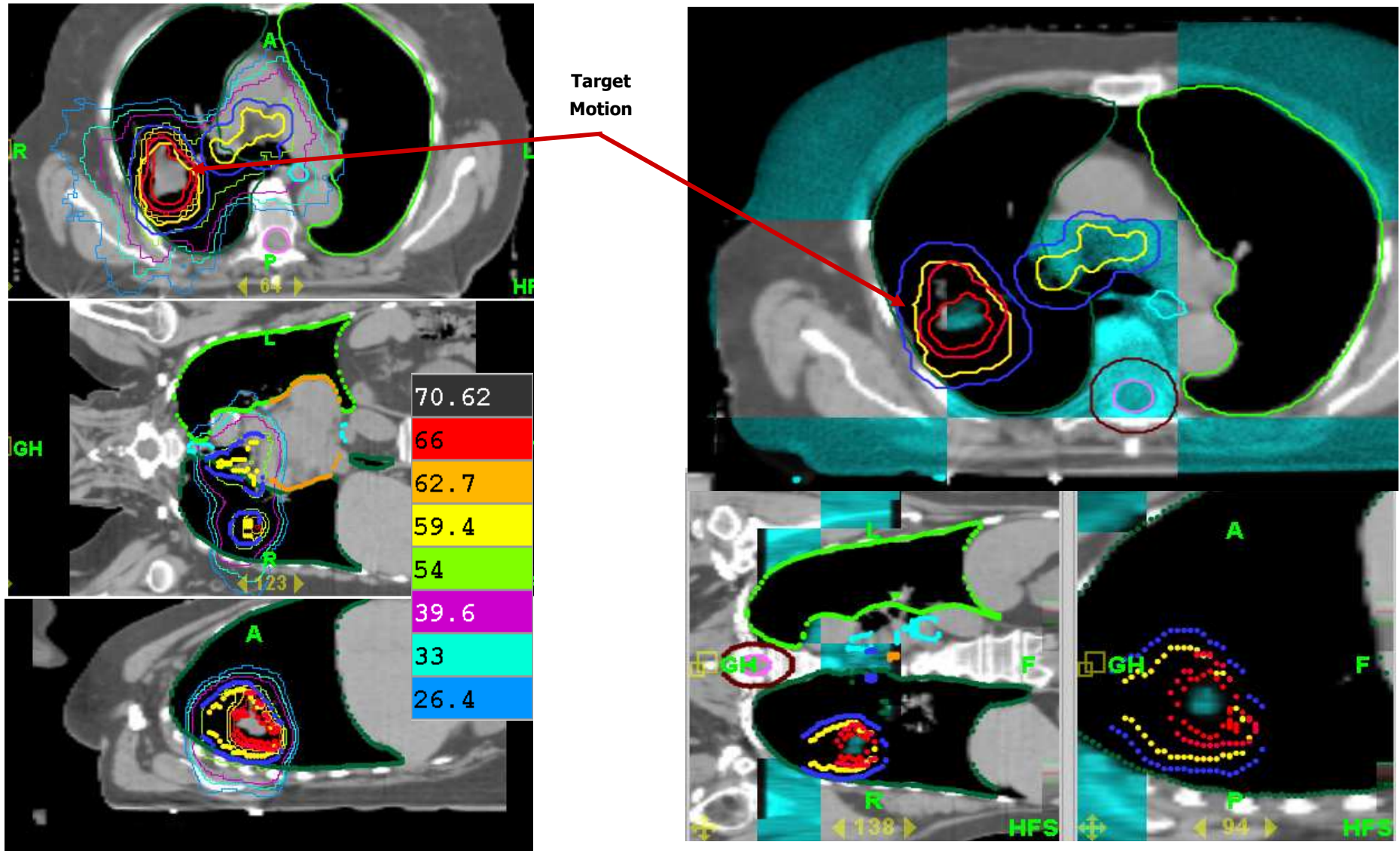




4DCT - MOTION MANAGEMENT 4DPET - MULTI MODALITY IMAGE FUSION

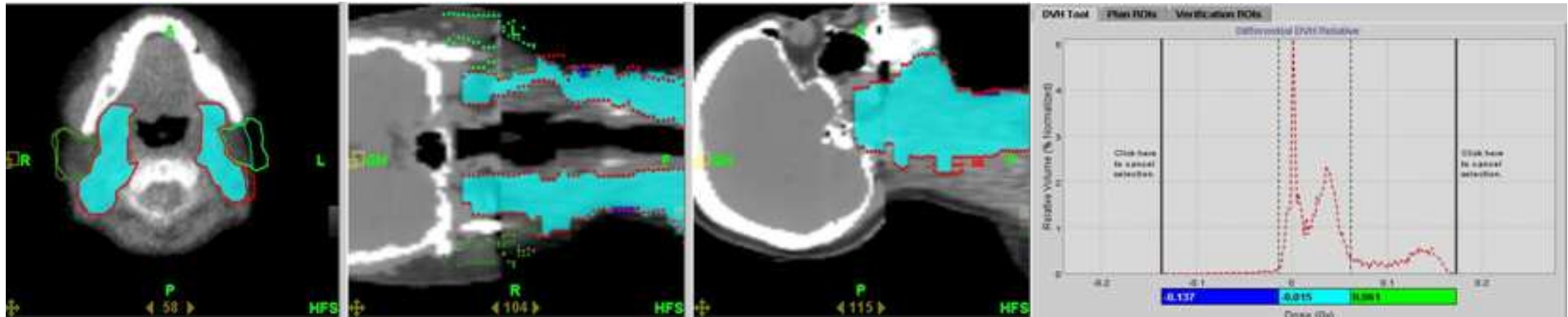


ADAPTIVE RADIATION THERAPY AND MOTION MANAGEMENT (4D-ART: RESEARCH AREA)

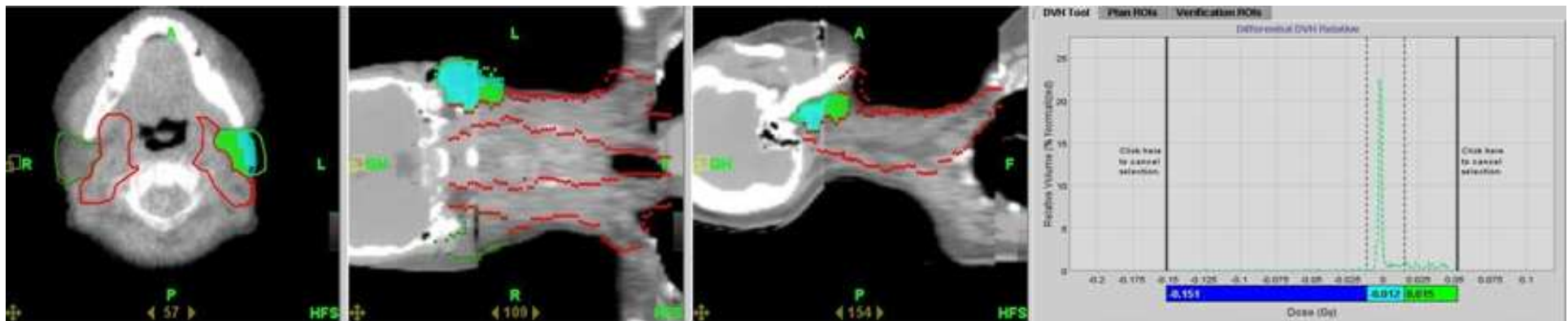


H&N ADAPTIVE CALCULATION STRATEGIES (Case I)

.....During treatment, the weight loss of 11 kg has changed the anatomy.....
The dosimetric evaluation calculated for re-contoured volumes on MVCT shows.....



5% of PTV vol. received 0,01 Gy /F less and a maximum of 0,06 Gy /F more (~1%Vol)



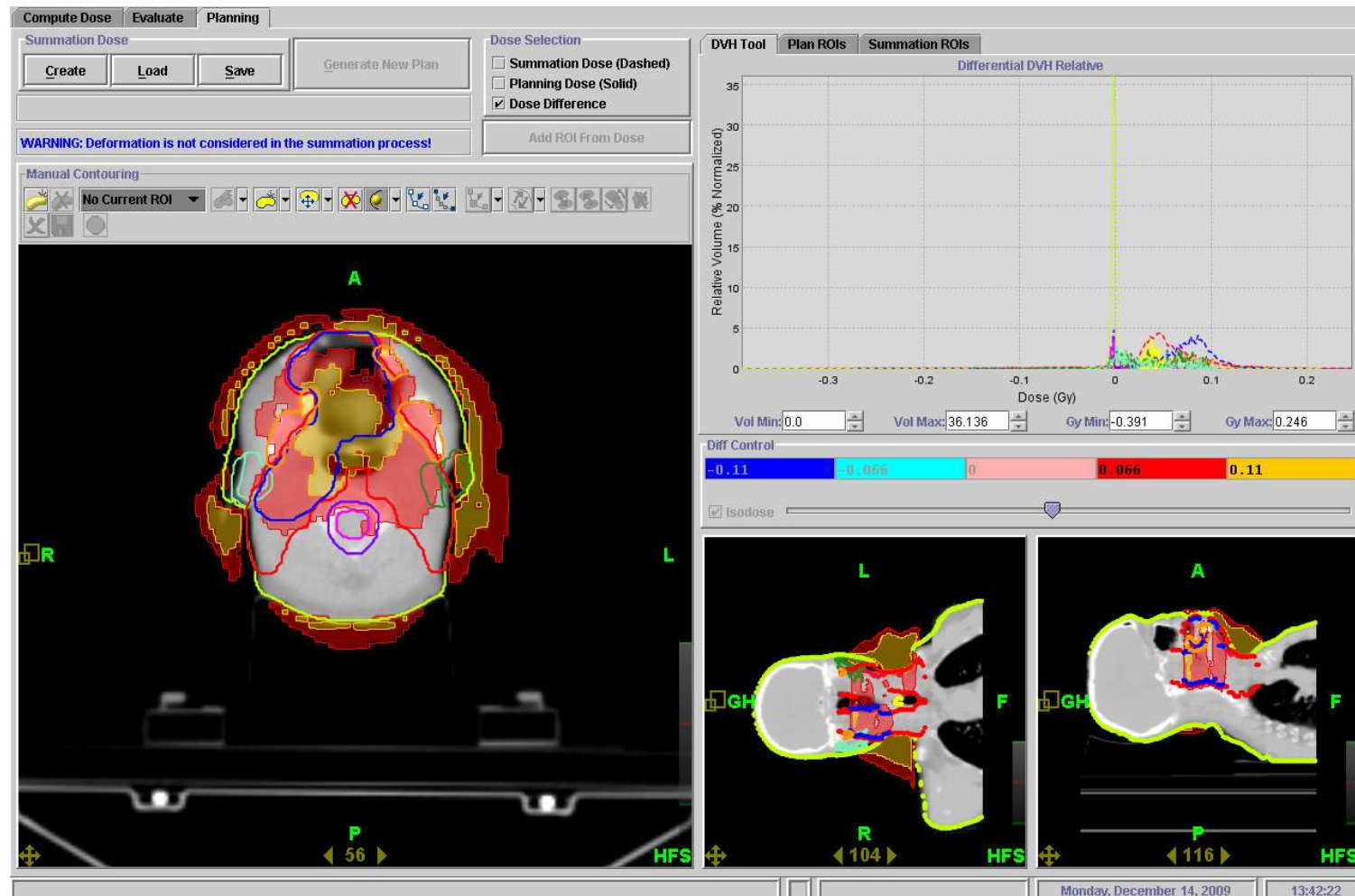
20 % of left parotid gland vol. received 0,01 Gy / Fx less

H&N ADAPTIVE CALCULATION STRATEGIES (Case II)

.....During treatment, the weight loss of 15 kg has changed the anatomy.....

The dosimetric evaluation shows high dose increase anywhere...

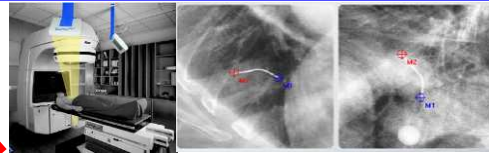
...The MVCT Daily check can guaranties the quality of the treatment changing and re-planning before any dosimetric error



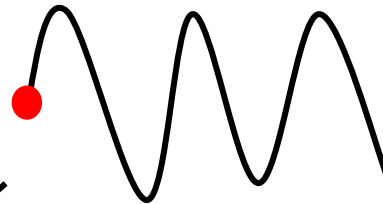
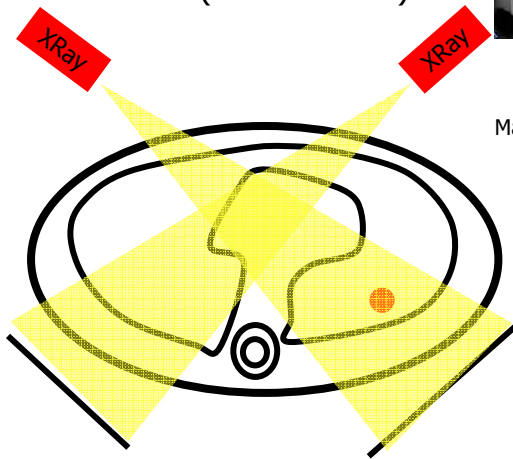
5% of PTV vol. received from 0.06 to 0,1 Gy /Fx anywhere

GATING vs. TRACKING (Breathing Model)

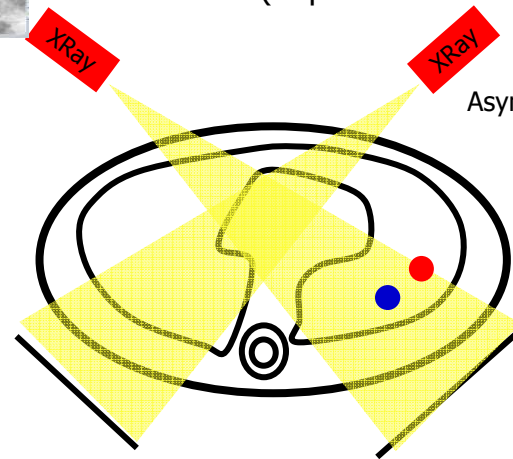
1° Point Of View
(Create Model)



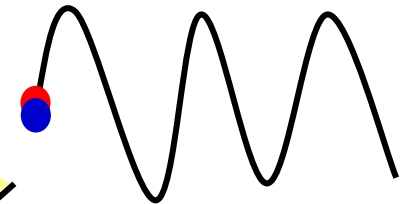
What's happen inside?
You need Marker
Maybe the Xray doesn't see the tumours



2° Point Of View
(Reproduce the Model)



You need markers!!
Asynchrony of the model, means a mistake



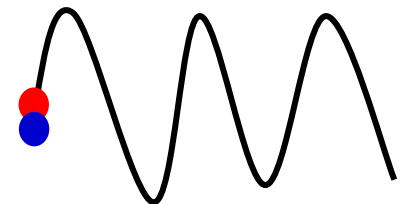
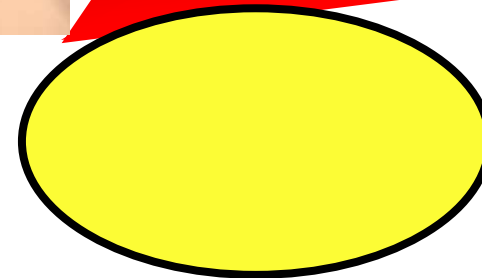
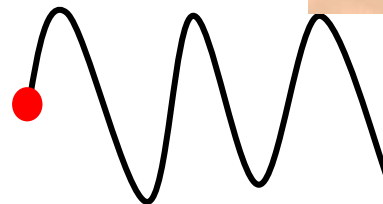
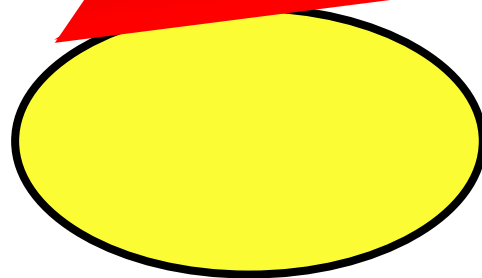
Tracking

What's happen inside?
With Tracking, you don't know!



Tracking

You don't see anything inside....
.....you believe in your model

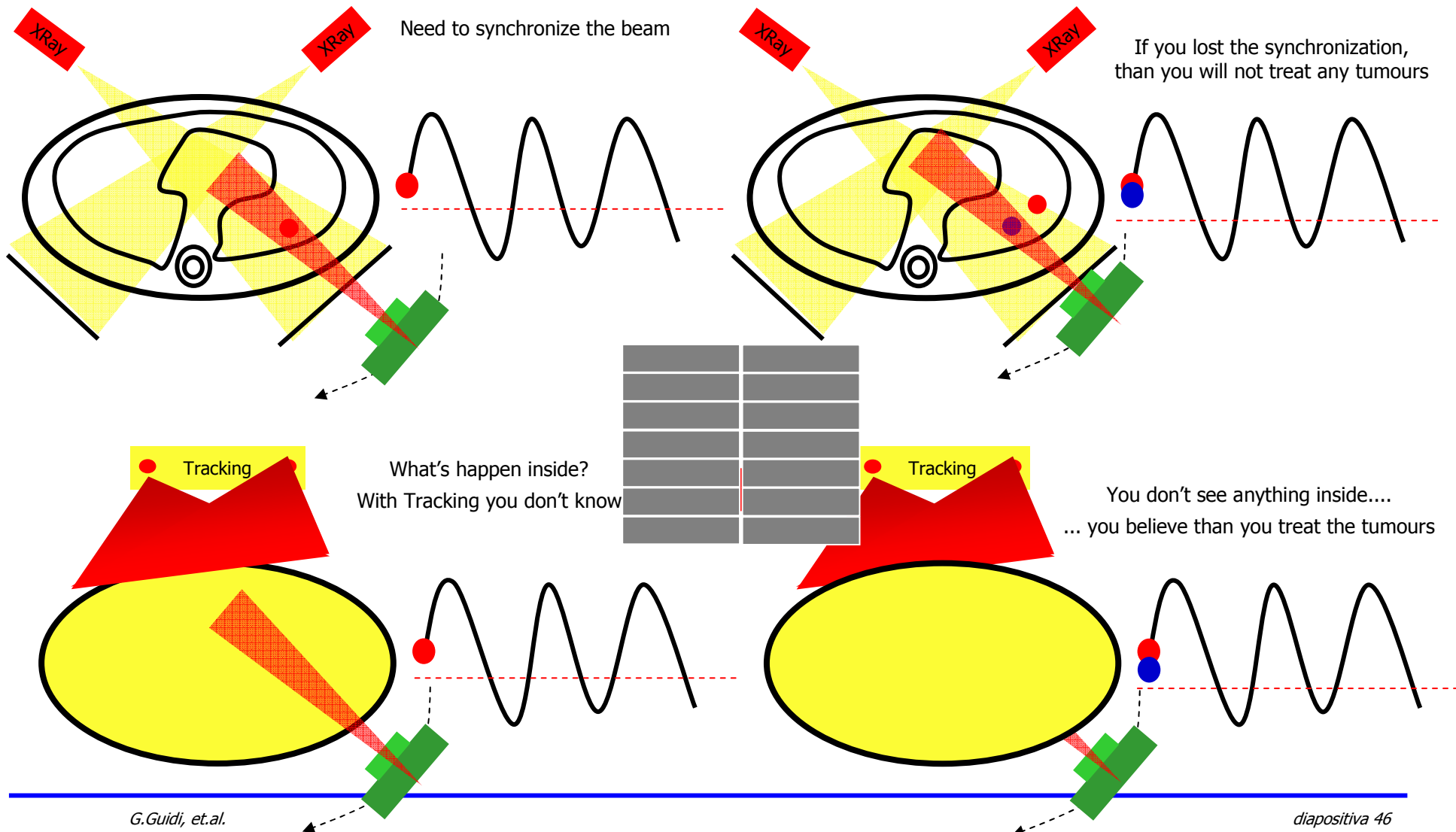


GATING VS. TRACKING

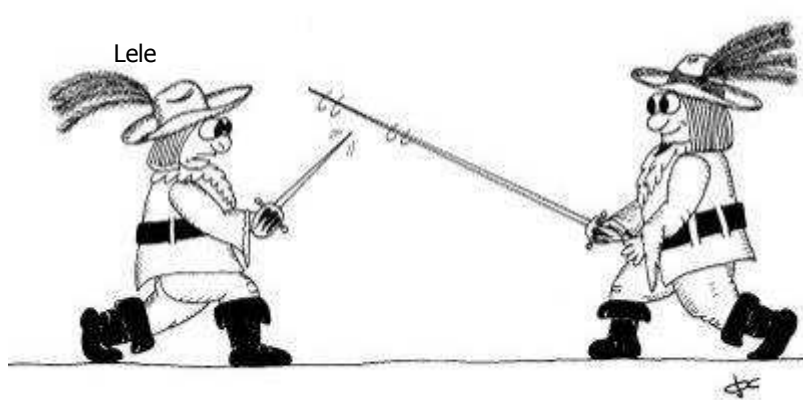
Breathing Surrogates are the worst way to treat patients

Outside Point Of View

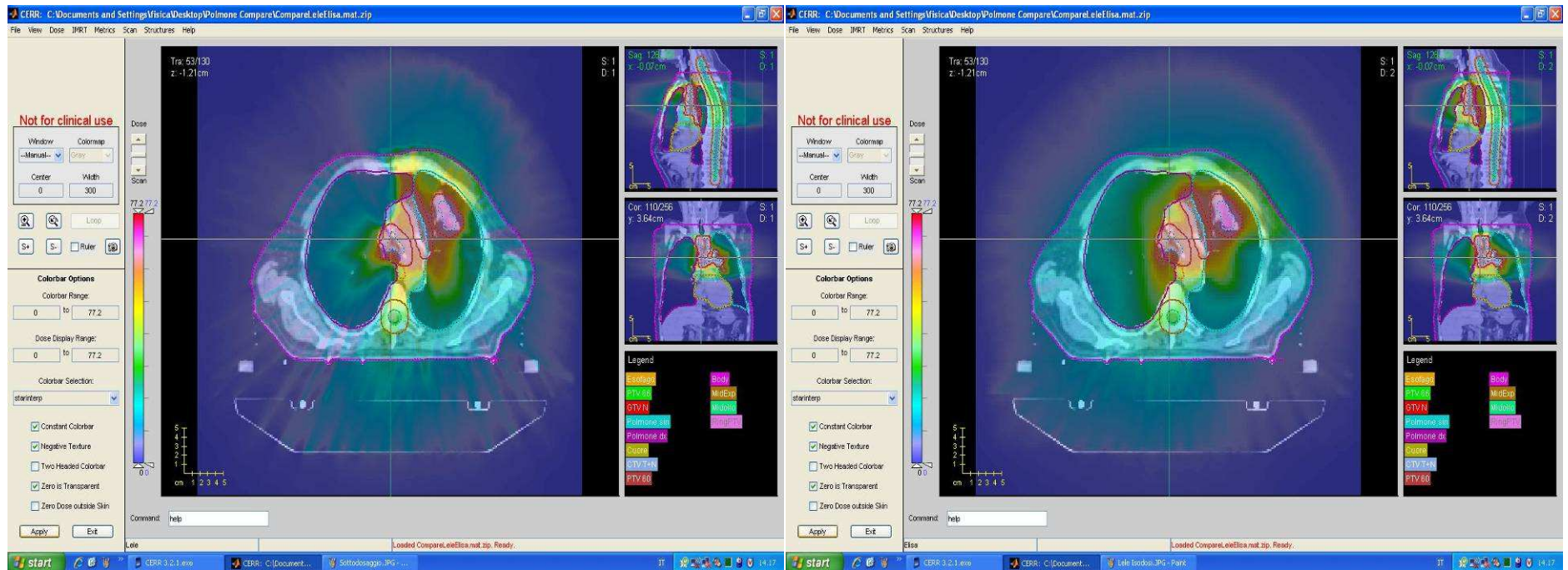
Inside Point Of View



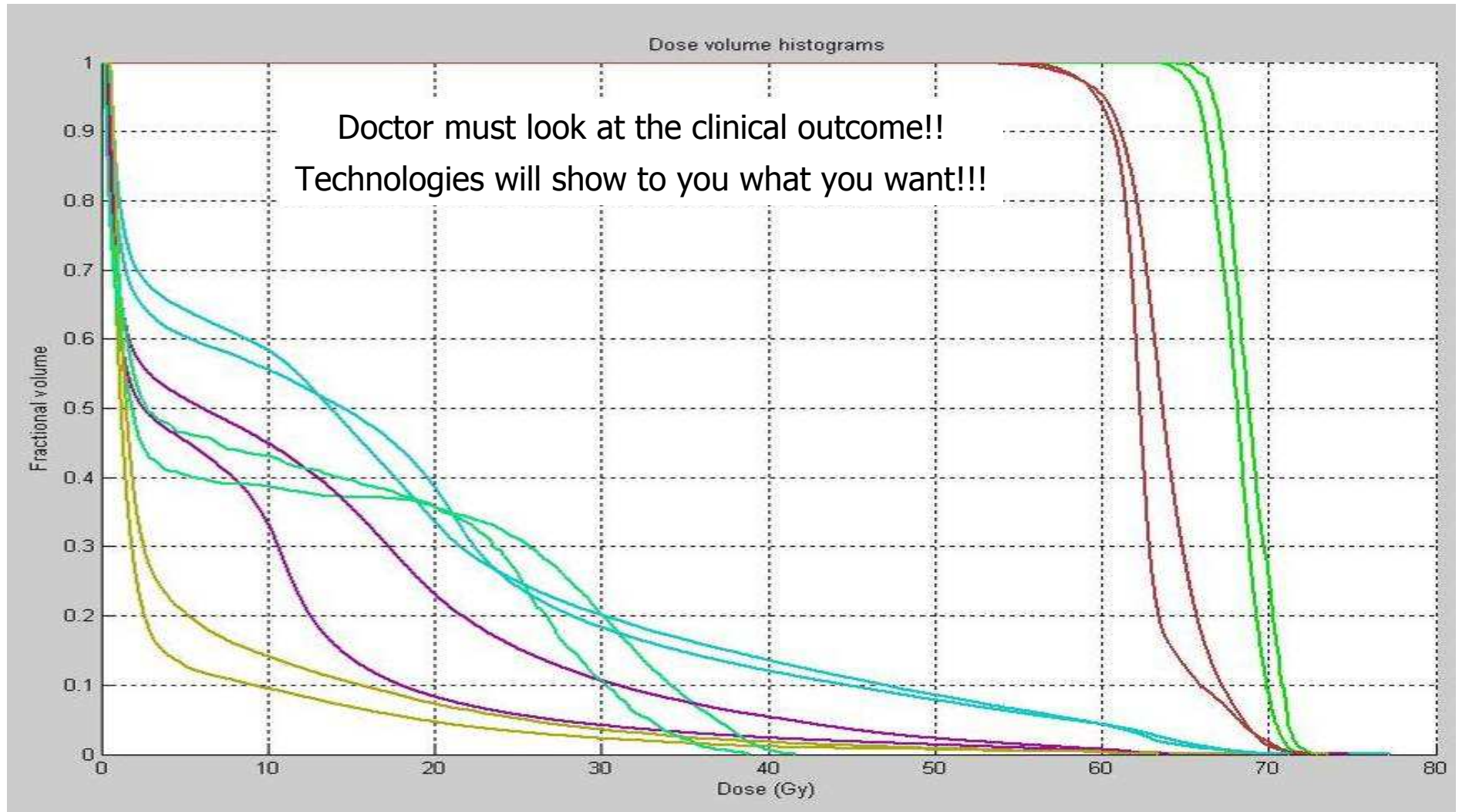
THE DUEL.....



1. Same Patients
2. Same Doctor
3. Same Contours
4. Same Constrains
5. Same Target Objectives
6. Different Point of View
7. Which is the best plan?



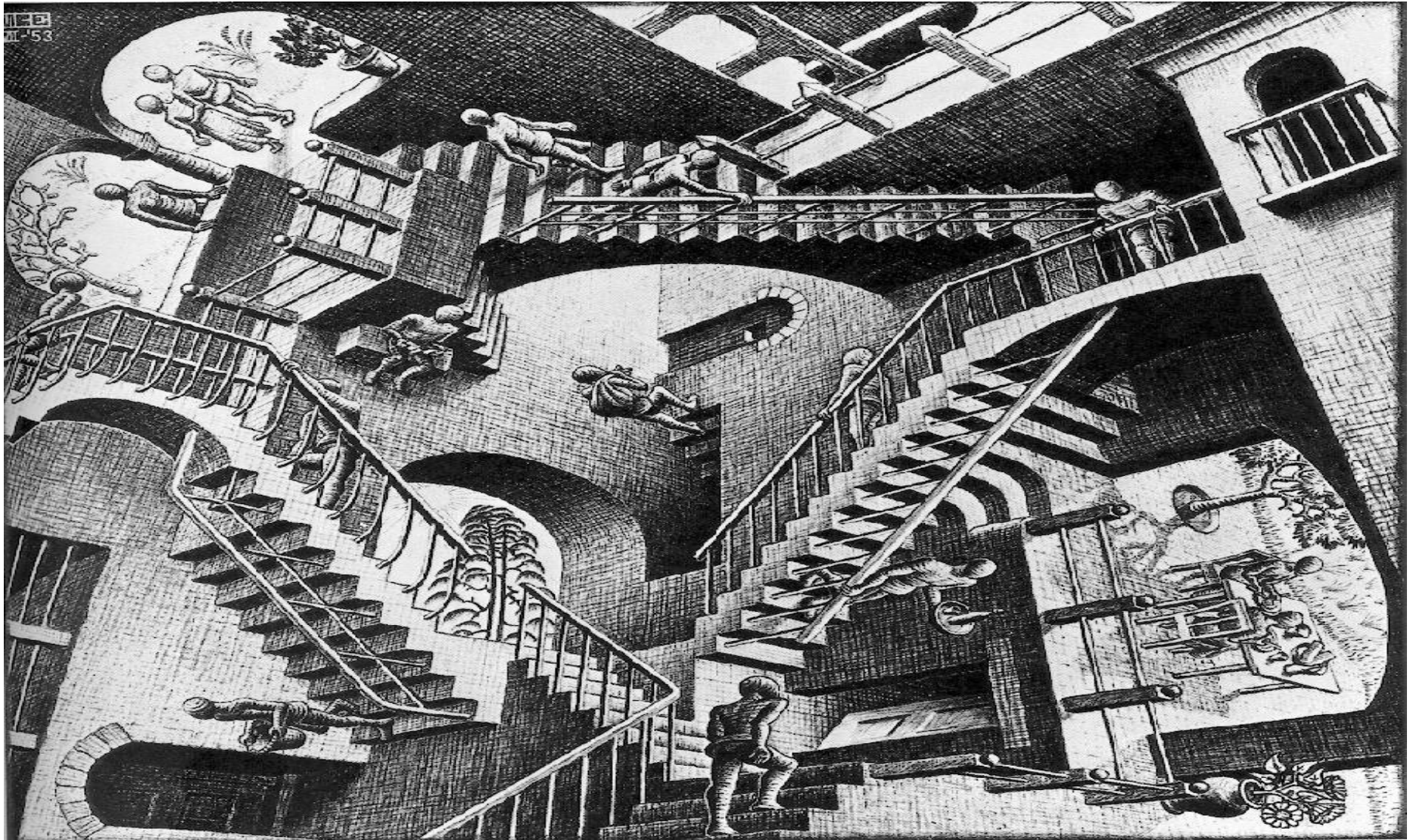
DVHs COMPARISON (AHHGGGG!!!!.....)



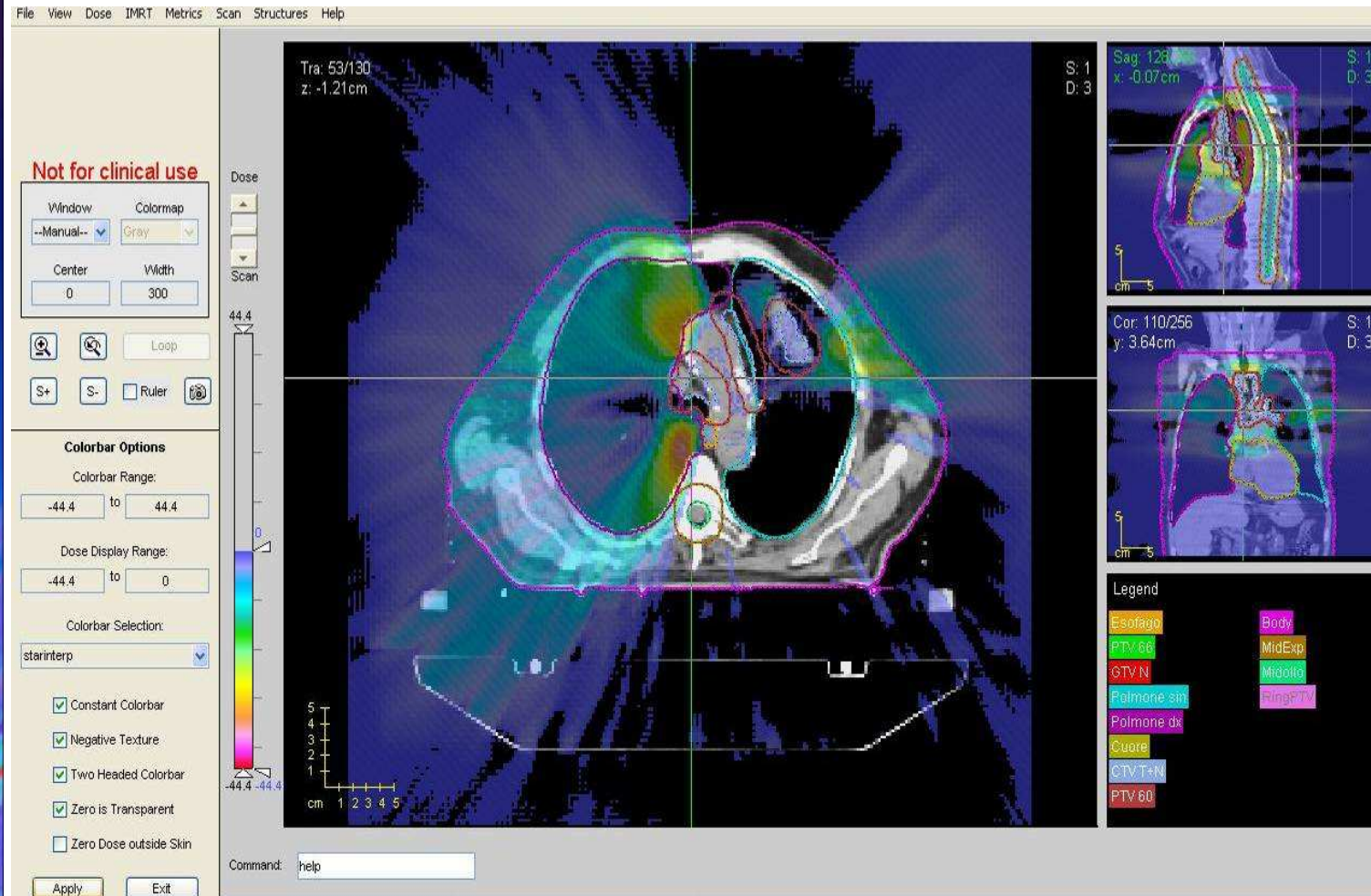
*May be, compare DVH is not the best way to compare technologies...
....and for sure is not the right way to compare the clinical outcome*



ESCHER : DIFFERENT POINT OF VIEW



OVERDOSED – UNDERDOSED (LOW DOSE LEVEL)



Objectives (1°PoV)

- Save Healthy Lung
- Minimize Integral Dose
- OARs Objectives
- Treat Target

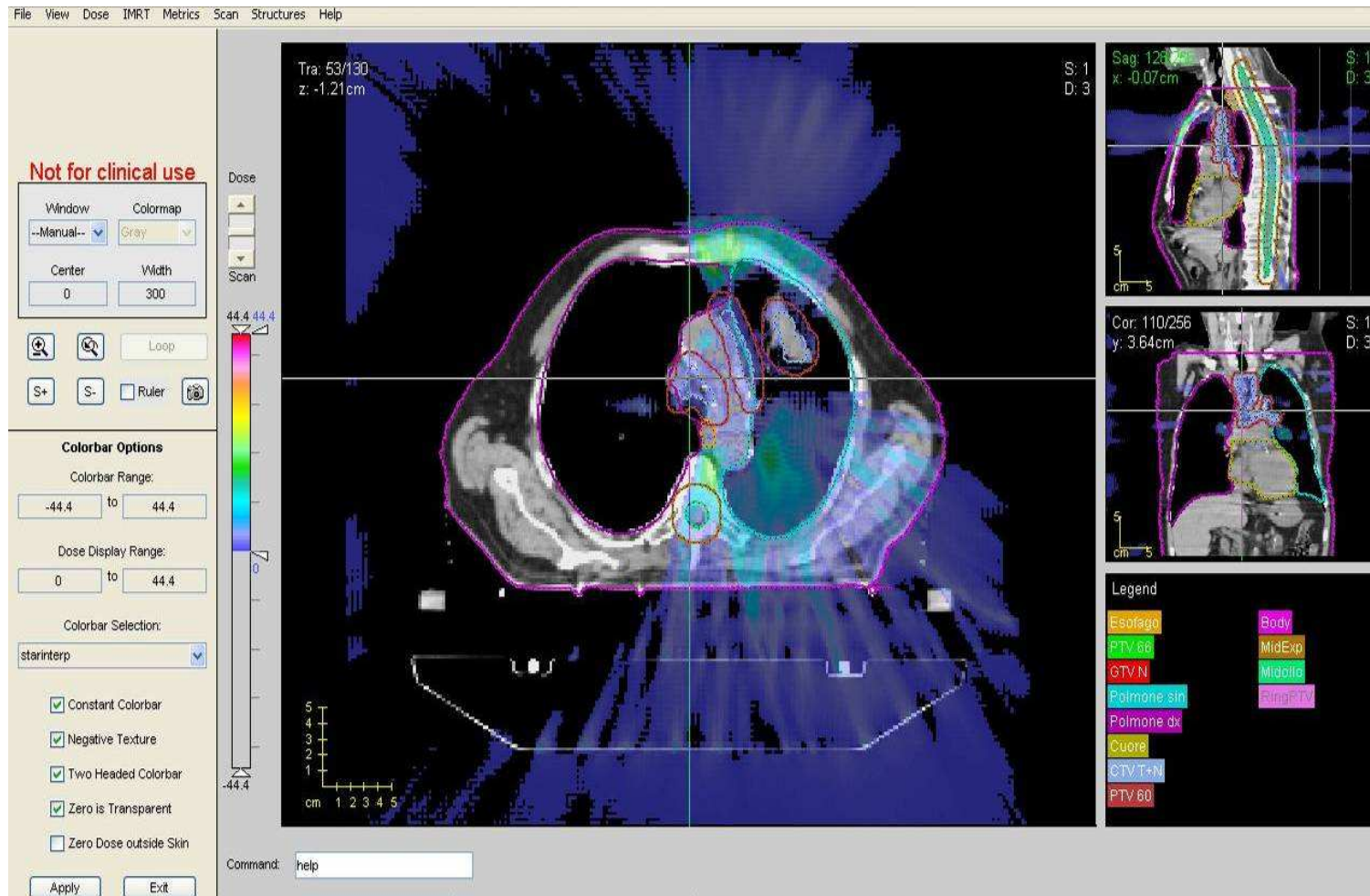
Objectives (2°PoV)

- Target Objectives
- OARs Objectives
- Save Healthy Lung
- Minimize Integral Dose

Lung Dx: Overdosed

Target: Underdosed

OVERDOSED – UNDERDOSED (HIGH DOSE LEVELS)



Objectives (1°PoV)

- Save Healthy Lung
- Minimize Integral Dose
- OARs Objectives
- Treat Target

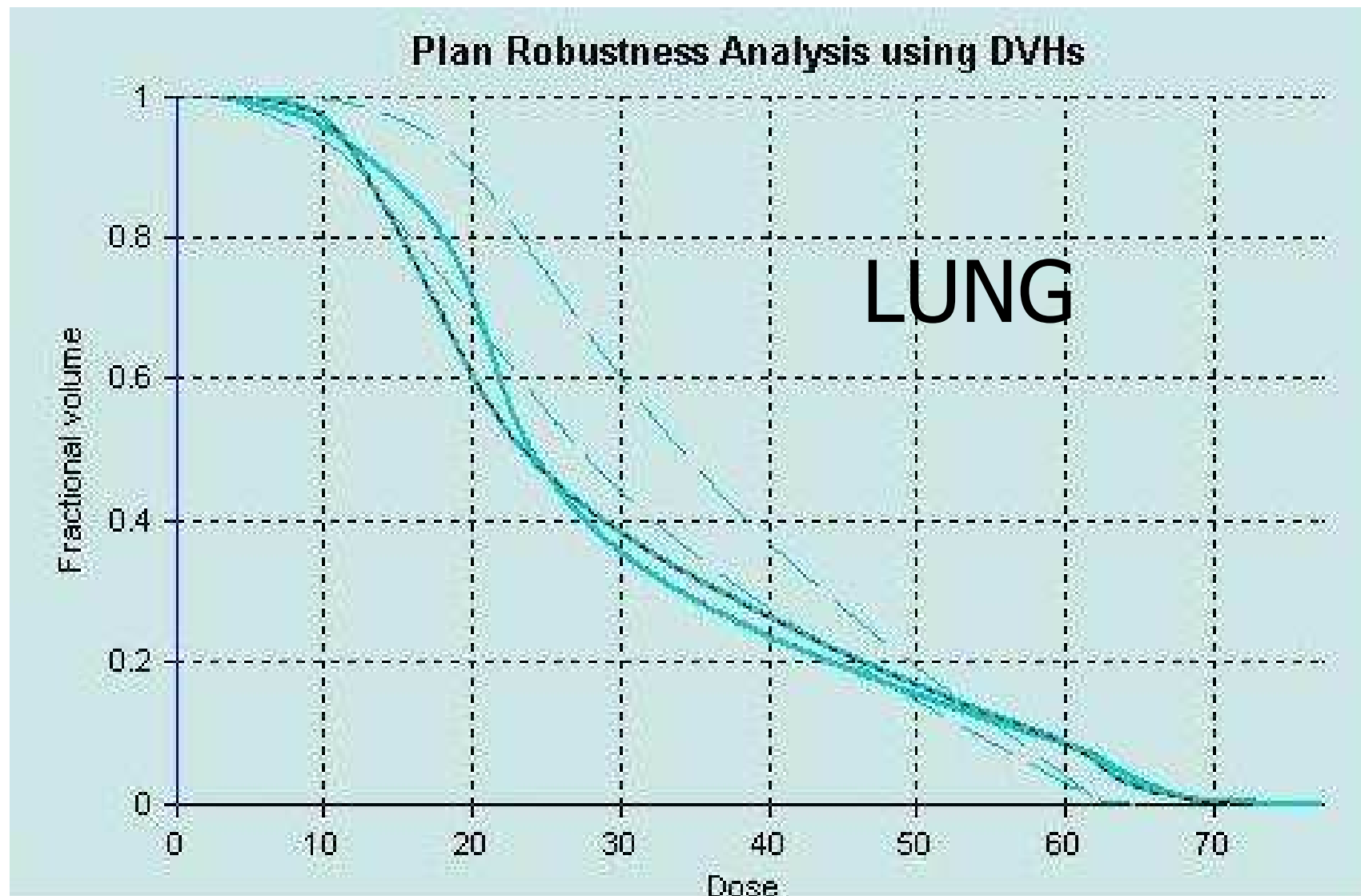
Objectives (2°PoV)

- Target Objectives
- OARs Objectives
- Save Healthy Lung
- Minimize Integral Dose

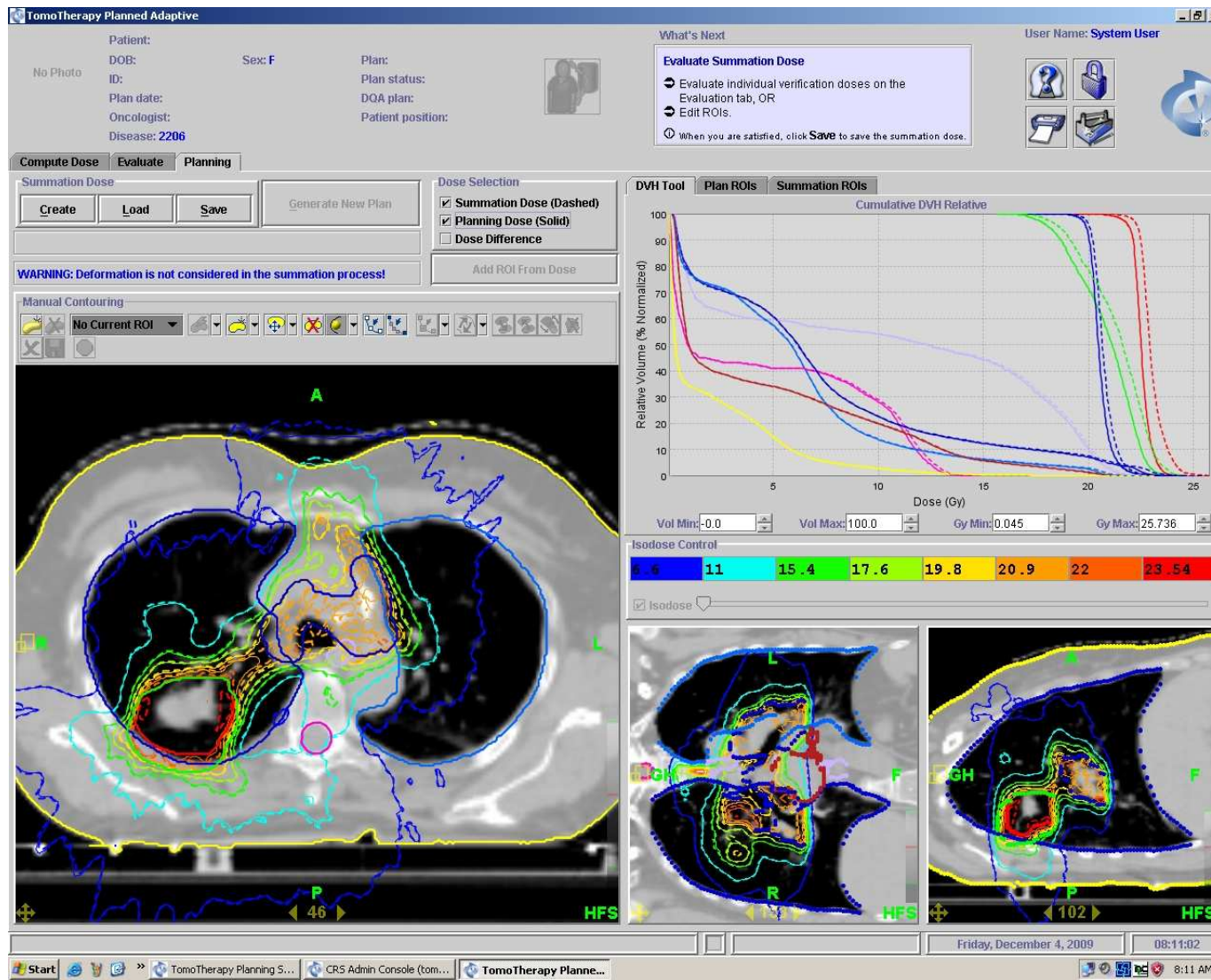
Lung Sin: Overdosed

Target: Underdosed

PATIENT SYSTEMATIC & RANDOM SETUP ERROR EFFECT (2mm of shift close to the tumours)



LUNG ADAPTIVE DOSE CALCULATION (... NOT EVERYTHING IS PERFECT...)

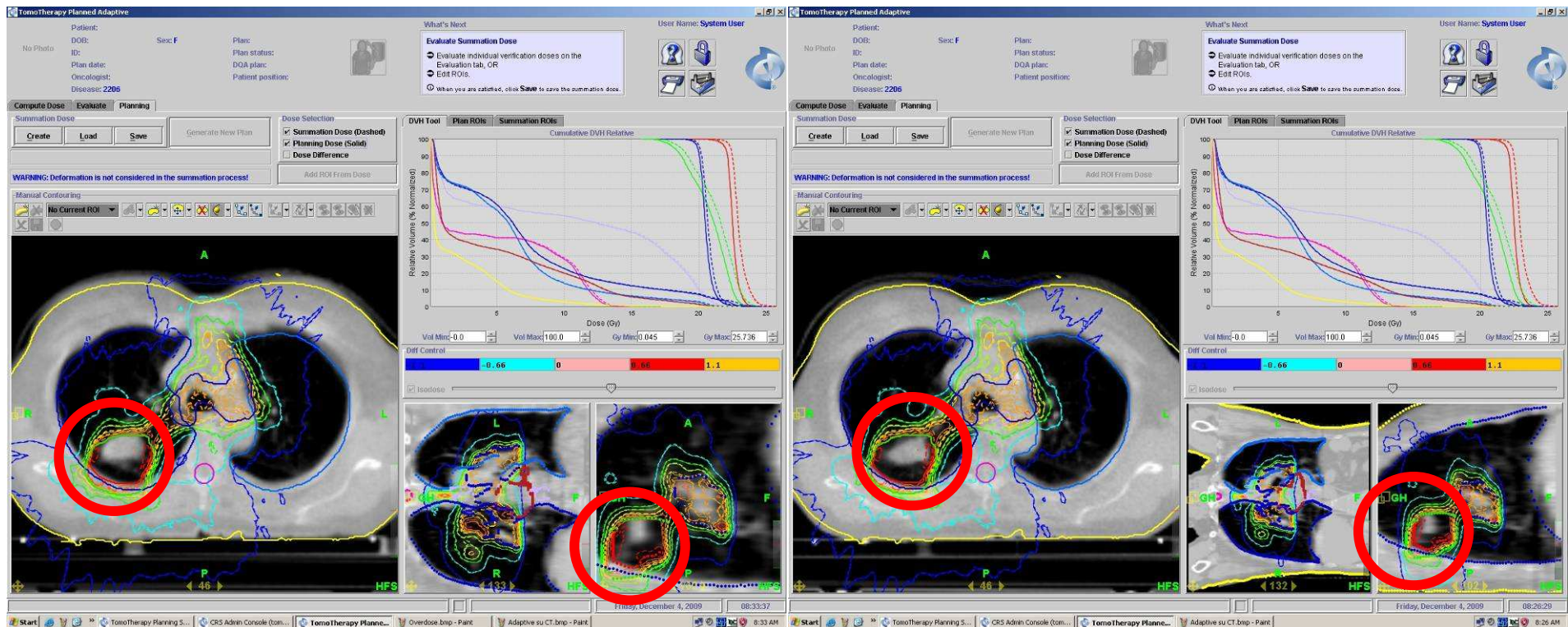


ISSUE UNDER INVESTIGATION:

1. Dosimetric error due to the algorithm?
2. Target delineation
3. Target Movement (Intra/Inter fraction)
4. Dose Lung Estimation
5. Dose at the interface (Bone/Lung/Fat)
6. Volume effect (image down sampling)
7. MVCT vs. KVCT
8. Treatment Dose Output
9. Plan Optimization and Parameters?
10. Operators
 - Doctor
 - Physicist
 - Therapist

... but the patient can have daily dose check of the dose delivered and the plan can be optimized during the cycle...

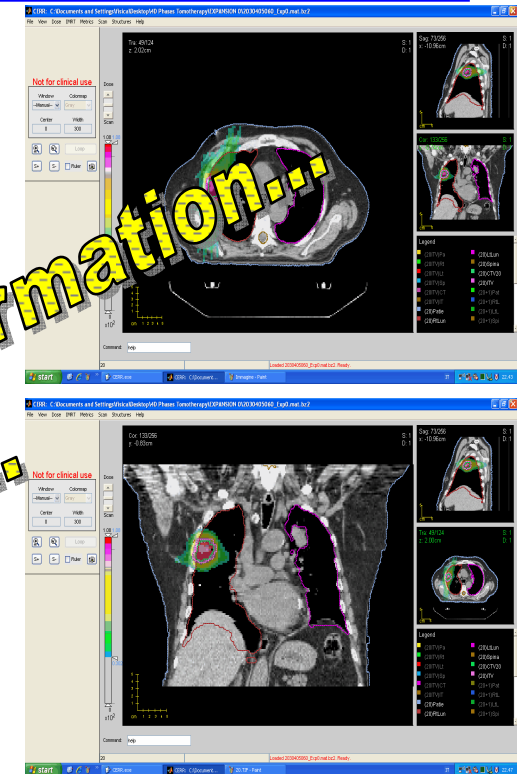
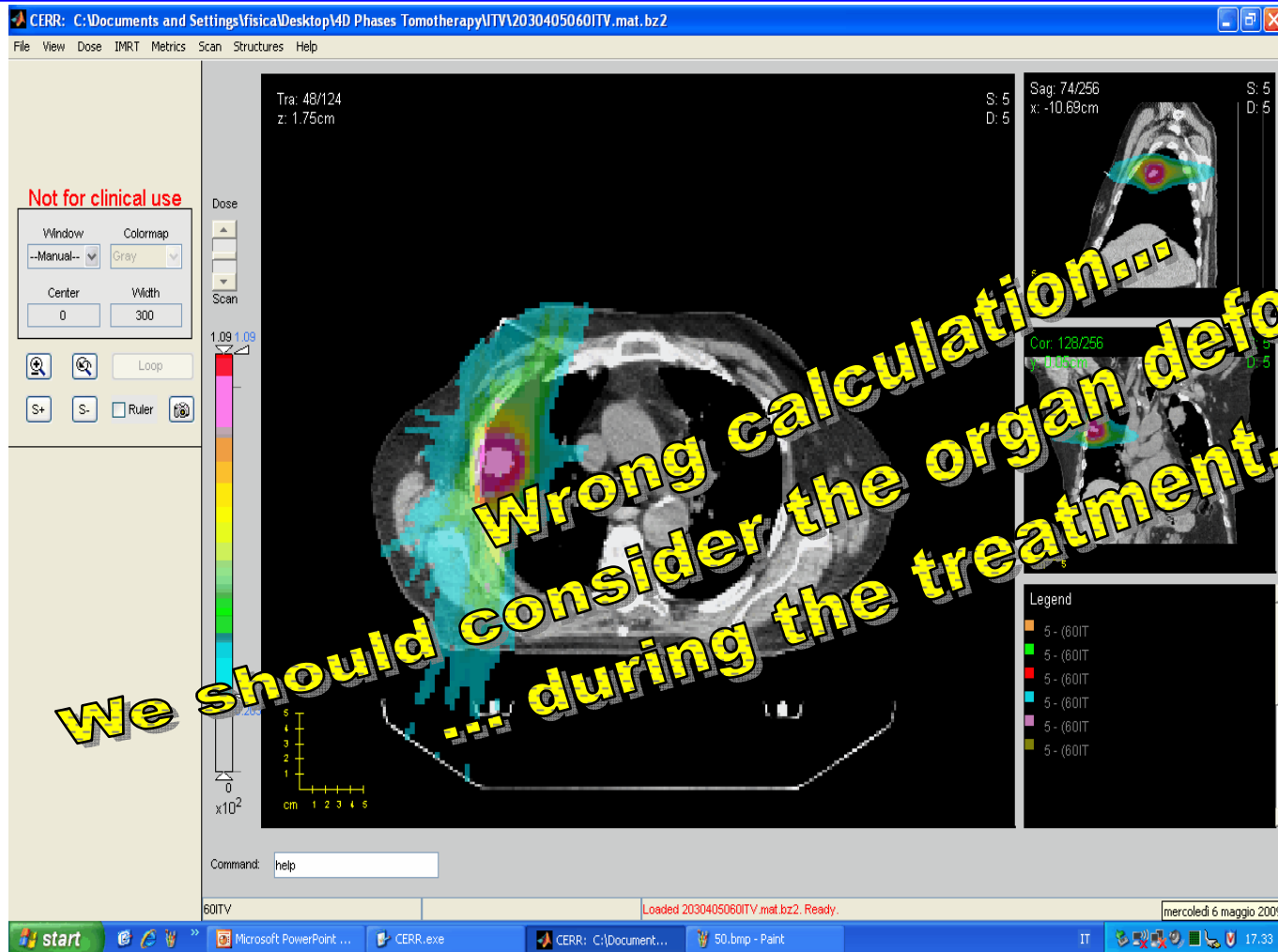
MVCT1 vs. MVCT2



- Different target dimension?
 - Is Day1 vs. Day2? (Interfraction)
 - Is Time1 vs. Time2 (Intrafraction)
 - Is the tumor shrinkage ?
 - Is the duty cycle? (Breathing)
 - Different dose calculation ?
 - Where? In tumour or OAR?
- 1. Change the dose due to the OARs or Tumour position?
- 2. Isn't it during the respiration breathing?
- 3. Why should i do a MVCT before and after the treatment?
- 4. Why should I believe at the MVCT of multiple days?
- 5. Is important the Volume effect for goals of the entire treatment?

... may be the best way to care the patient, is check every day using a easy way

ORGAN MOVEMENT INFLUENCES & 4D-DOSE ACCUMULATION (RESEARCH AREA)

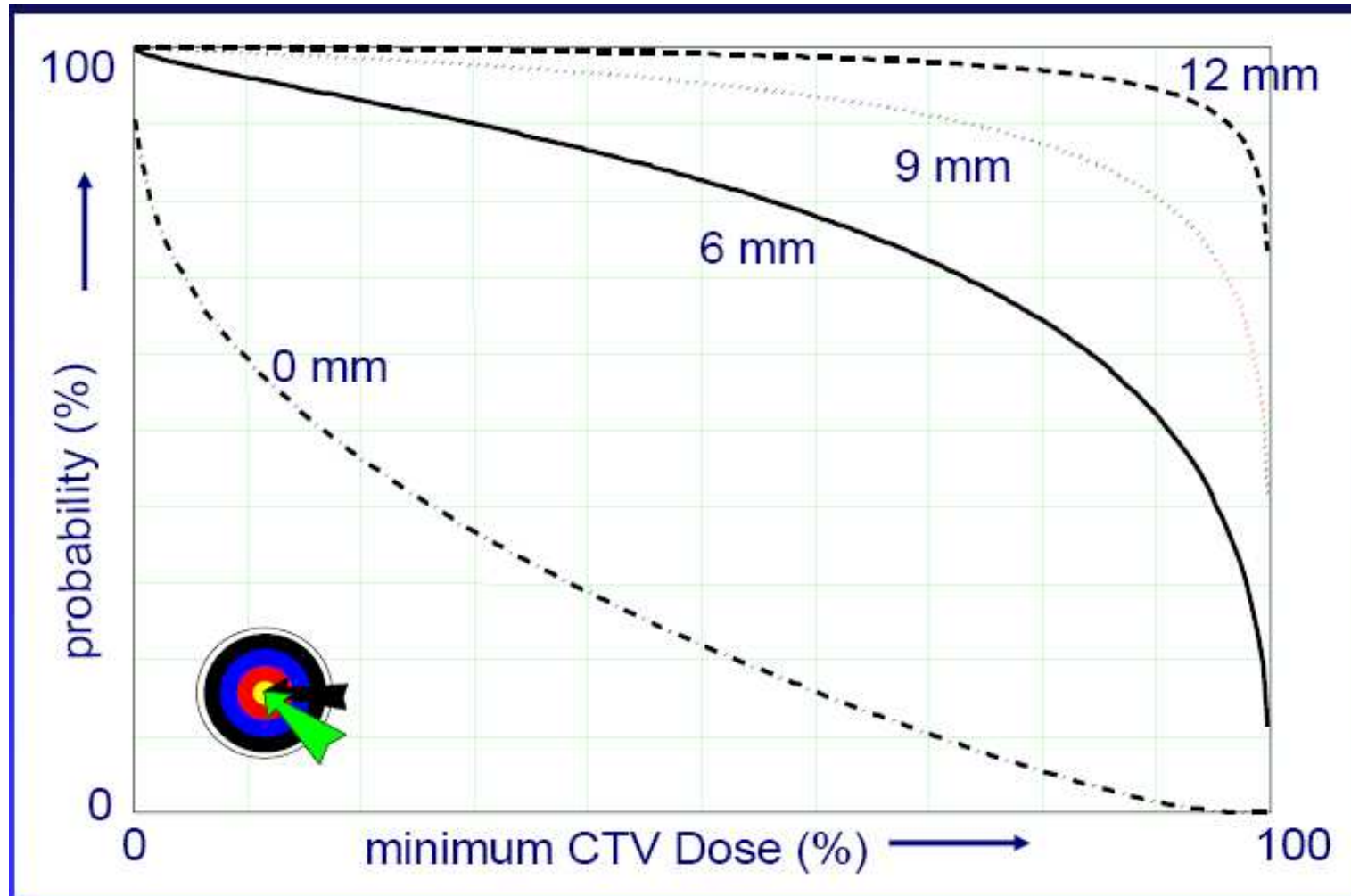


Dose Matrix (Phase 20%) +
Dose Matrix (Phase 30%) +
Dose Matrix (Phase 40%) +
Dose Matrix (Phase 50%) +
Dose Matrix (Phase 60%) +

4D Dose Reconstruction

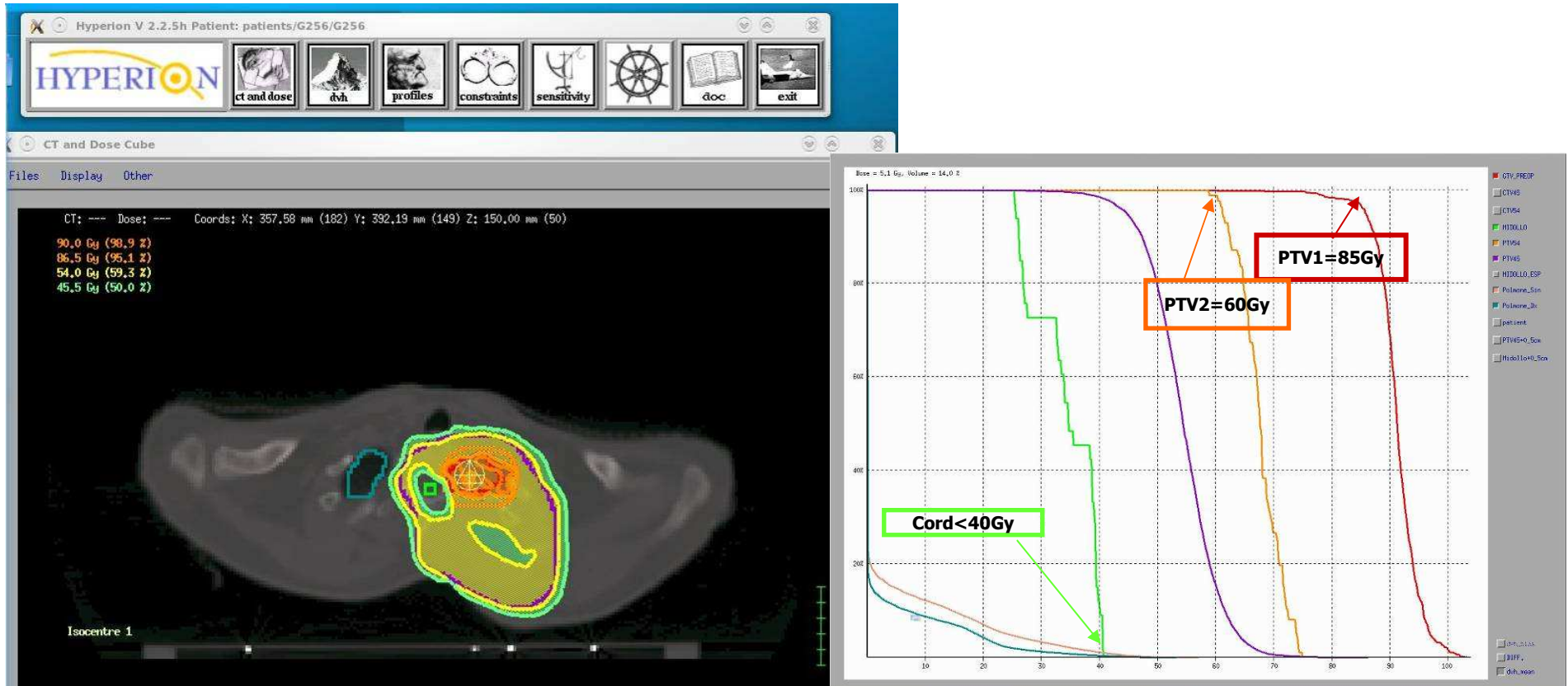
- 4D DOSE RECONSTRUCTION OF THE RESPIRATORY PHASES
- The Dose accumulation must include the organs deformation.... ADAPTIVE is not correct!!
- DVH is a Dose "reconstruction" of the Volume... DVH is not a clinical outcome!!

CAN I REDUCE THE MARGIN ?
(WITH TOMOTHERY FOR US IS LIMITED AND UNDER INVESTIGATION)



Courtesy of Marcel van Herk – ESTRO 2009

PROTON - THERAPY (Proton-Tomo?)



Simulation of Protons Treatment with multiple gantry angles between -20 to 120°(by G.Guidi 2009)

Few questions in my mind.....may be I need to change my mind!!!

...are we sure about the dose calculation? Is there any clinical impact or benefit vs. Tomotherapy with Photons

...we will try to investigate the problems comparing photon (using Tomo) and proton (collaboration with CNAO and ATrep)

I hope, one day, to work with Protons (by G.Guidi 2010)

TAKE HOME MESSAGES

- Tomotherapy
 - Innovative machine
 - Faster and relatively easily to implement
 - Flexible for clinical routine and requirements
 - Easy way to treat complex cases
- Morphological area have not or few limitations
 - Target Delineation
 - Organ Movement (Interfraction – Intrafraction)
 - Organ Constrains
 - Fractionation based on Evidence Base Medicine data
- Multiple approach can be done and can be found
 - Different plan optimization parameters (Point of View)
 - Clinical objectives
 - 4D Tracking / Gating (Research area)
 - TBI and TLI (Research area)
- Doesn't exist a best plan or a best machine
 - DVH is not the "absolute true"
 - Plan can not be robust due to the setup and organ movement (dose can change)
 - Daily patient check should be a must for the future (Setup, dose and adaptive re-plan)
 - Many issues for the physicist and physicians
 - Dose calculation
 - Algorithm
 - Adaptive strategies....
- Integral dose and prescription must be consider and evaluated
 - Woman fertility (Breast and contra lateral breast)
 - Second cancer induction
 - Paediatric patient
 -
 - IGRT Dose is a problem, but anyone should consider the same problem for the ARC Therapy with LINAC
- Management
 - Full optional should be a must also for Tomotherapy Inc.
 - Service out of clinical time (21.00-6.00)
 - Service full risk also for upgrade and update

It is not perfect, but it's a "good" technology to try to fight the cancer!!

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- G.Gottardi
- G.Guidi

Dosimetrist

- L.Boni
- L.Morini
- A.Bernabei

Ex-Student

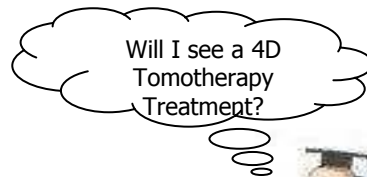
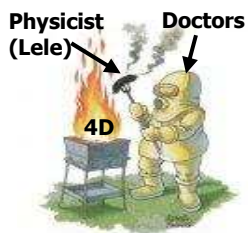
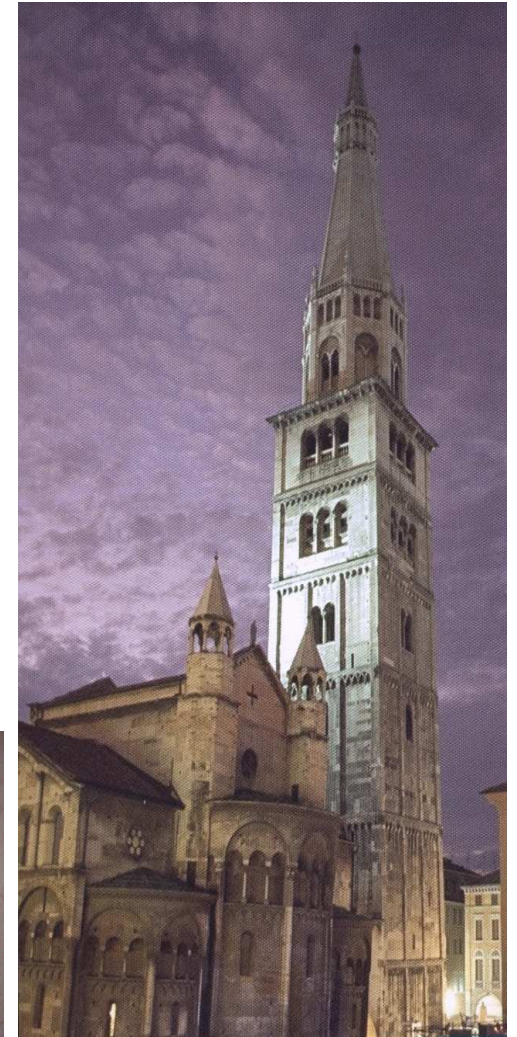
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- G.Tolento
- E.Turco
- All thereapist



In my mind: "Thank you guys, without you would not been possible this!"

Special Thanks to
Elisa, Luciano & Luca

"... under the "Ghirlandina" Tower....
.....new opportunities and ideas are growing ...
...and many people are working on it"

THANK YOU FOR YOUR ATTENTION AND INVITATION



“That’s too much!!!”

(Praha 2009)

