Radioterapia dei tumori polmonari e movimento respiratorio: Incertezze nella fase di planning e di esecuzione del trattamento

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RADIATION THERAPY IN EARLY STAGE LUNG TUMORS

Author	N. Pts.	Stage	Mean dose (Gy)	Loc. Rec. (%)	OS (5ys)
Jeremic (1999)	67	T1-2 N0-1	69.6	58	30%
Cheung (2000)	102	T1-2 N0-1	52.5	53	16%
Krol (1996)	108	T1-T2 N0	65.0	71	16%
Sandler (1990)	77	T1-T2 N0	60.0	56	17%
Morita (1997)	149	T1-T2 N0	64.7	44	22%

Reasons for limited success of dose escalation studies in non small cell lung cancer

- Limitations of CT imaging in delineating PTV
- Uncertainties related to motion of tumor and lung during image acquisition for treatment planning and treatment delivery
- Target definition and motion uncertainties necessitate using larger field sizes
- Ability to deliver tumoricidal doses limited by normal tissue tolerance

ICRU Report 62

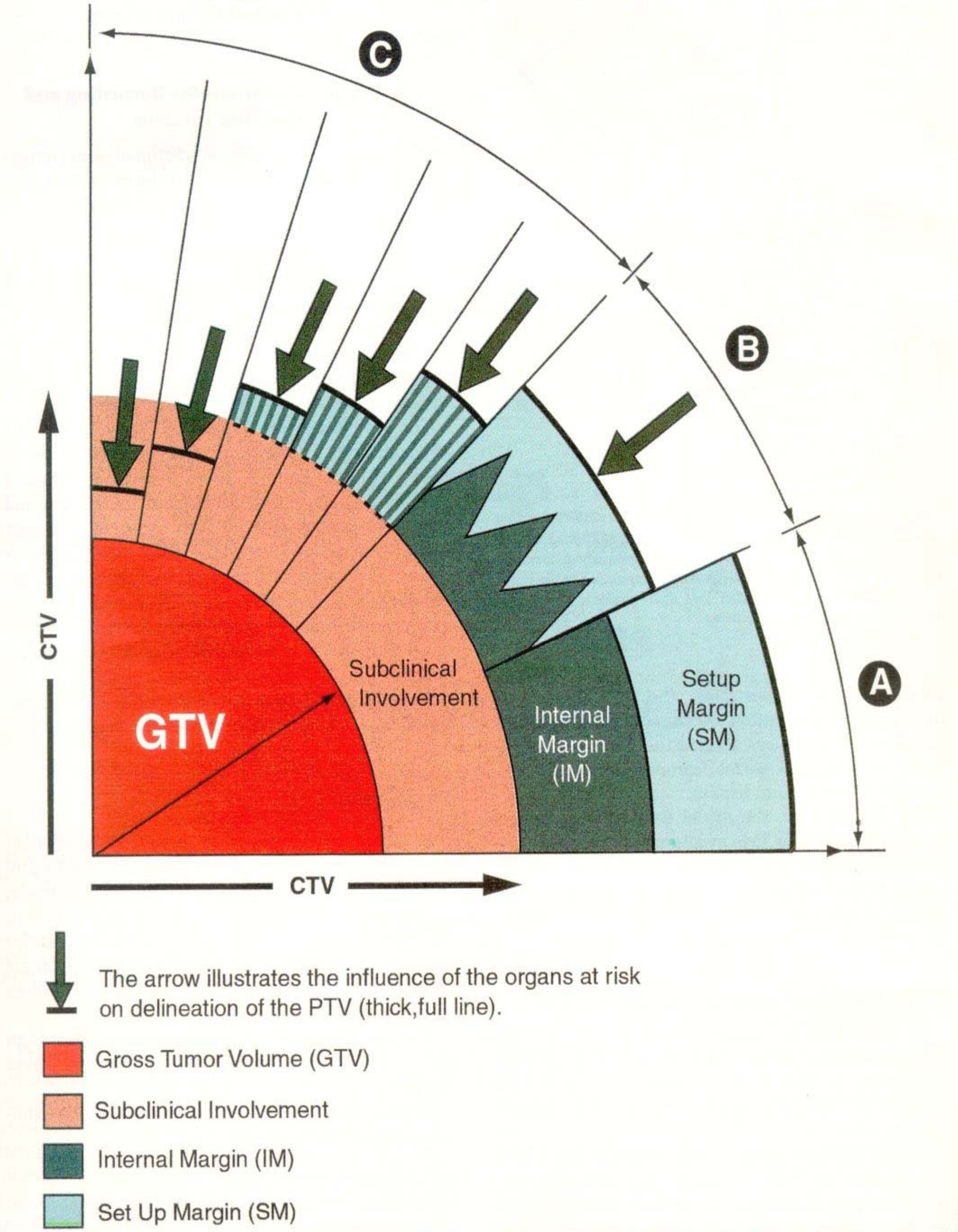
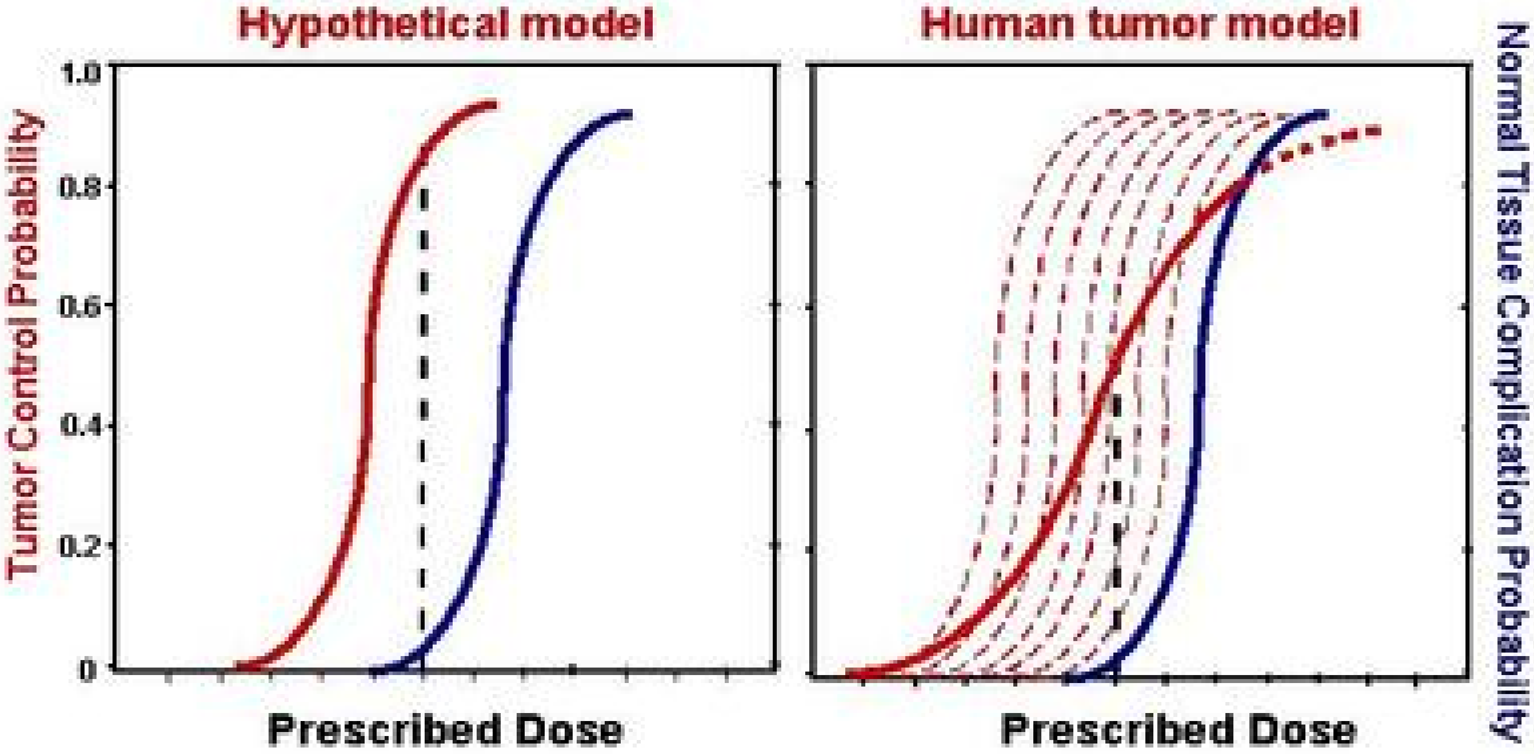


Fig. 2.16. Schematic representations of the relations between the different volumes (GTV, CTV, PTV, and PRV) in different clinical scenarios.

Internal margin related to organ motion

The determination of internal margin and set up margin, and the presence of OAR in the proximity of the target contribute to determine the " safety margin " around the CTV

TCP/NTCP Model of Radiotherapy



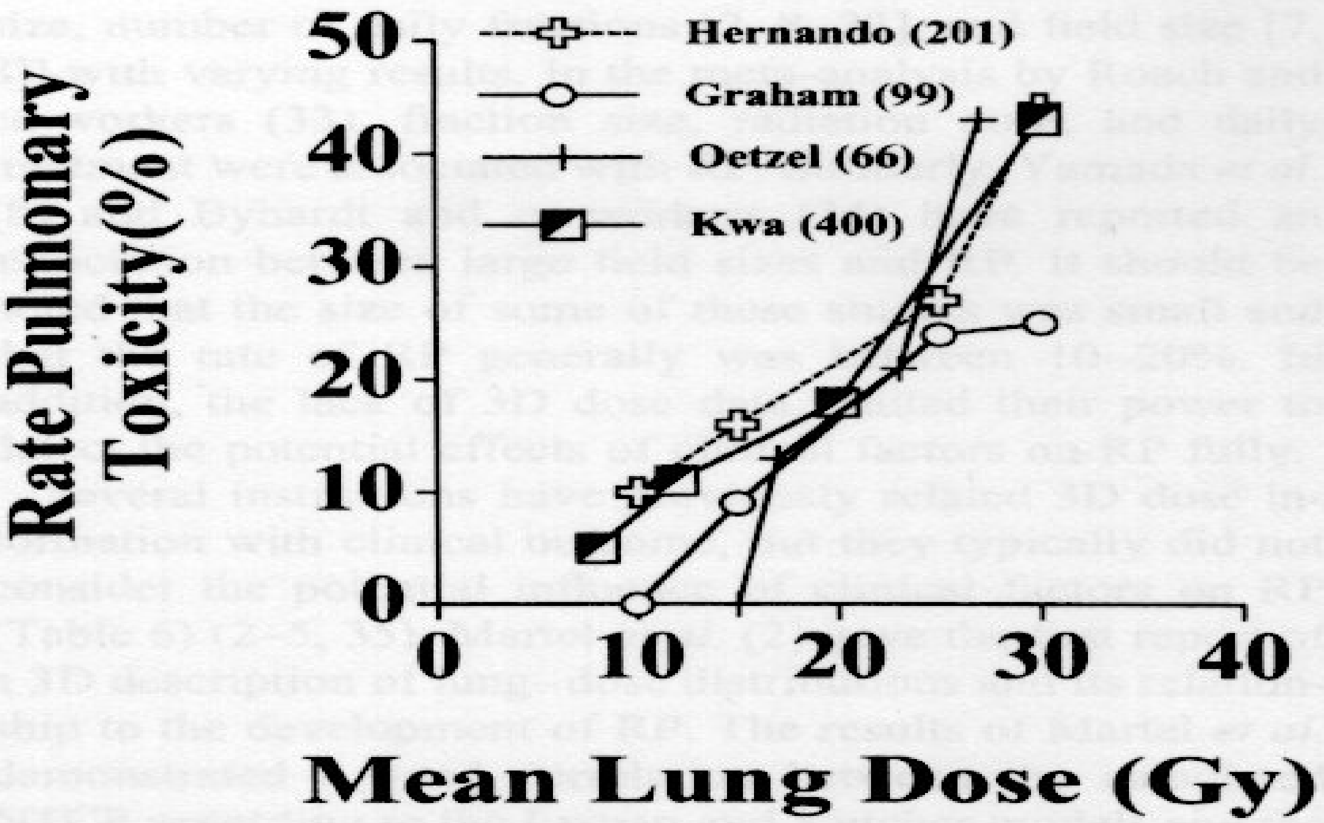
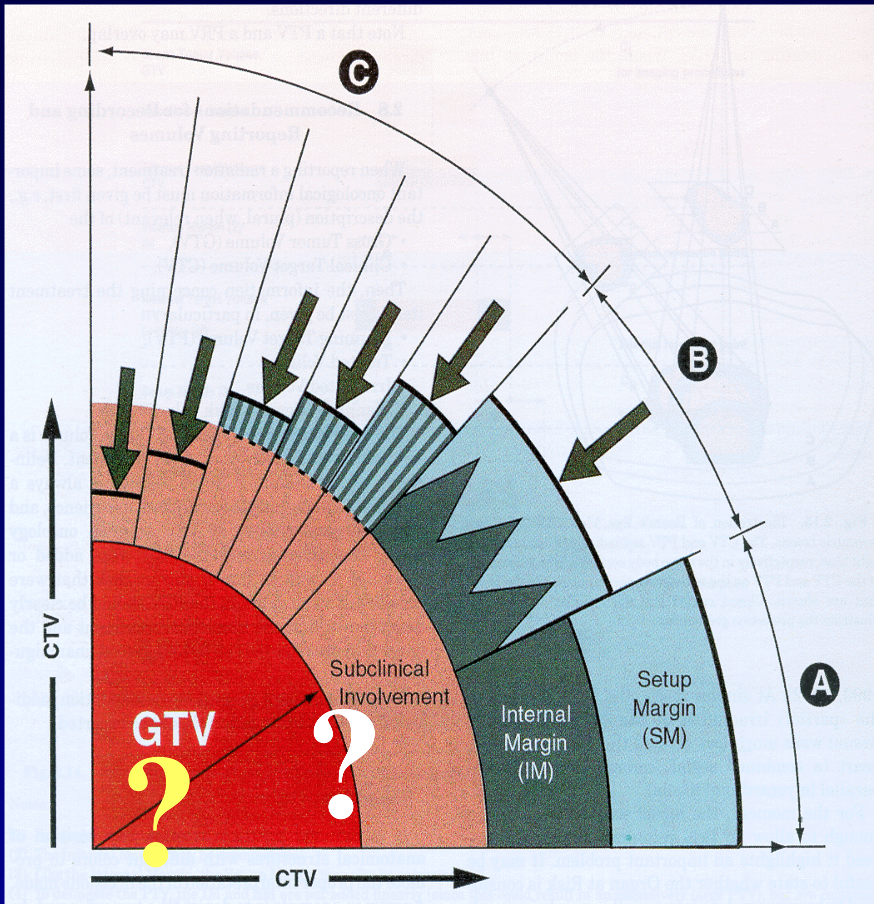
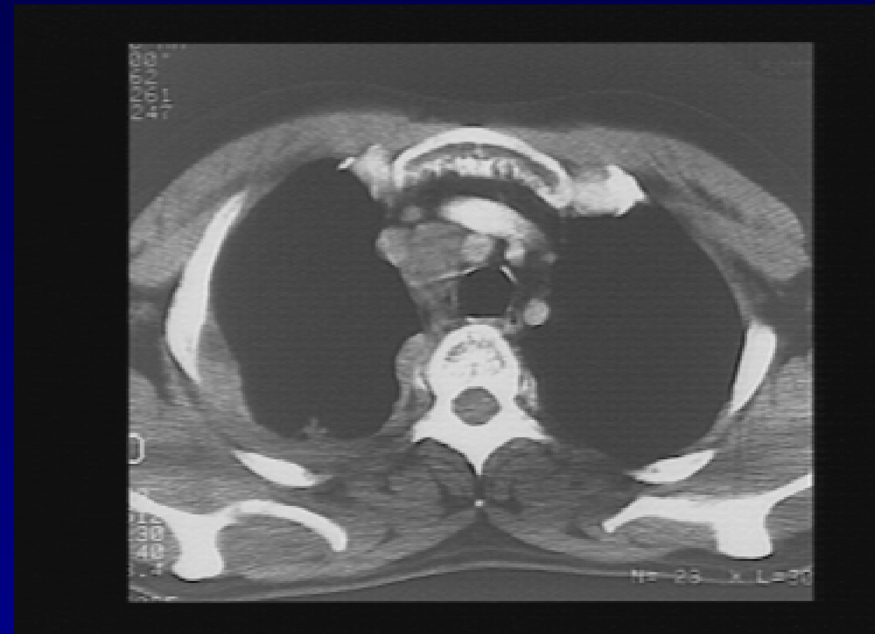


Fig. 1. Comparison between RP rate at different levels of MLD for patient subgroups in 4 studies. *x* axis values generally represent the middle of the subgroup ranges. The lowest *x* axis values (and highest *x* axis values) for the studies by Oetzel *et al.* (3) (separate organ analysis) and Graham *et al.* (4) (paired organ analysis) and the present study (paired organ analysis) represent the upper (and lower) limit of the MLD for these subgroups. Data gathered from Table 6. Number of patients in parentheses.

From: Hernando, M.L., IJROBP, 2001

IMPLICAZIONI NELLA FASE DI PLANNING





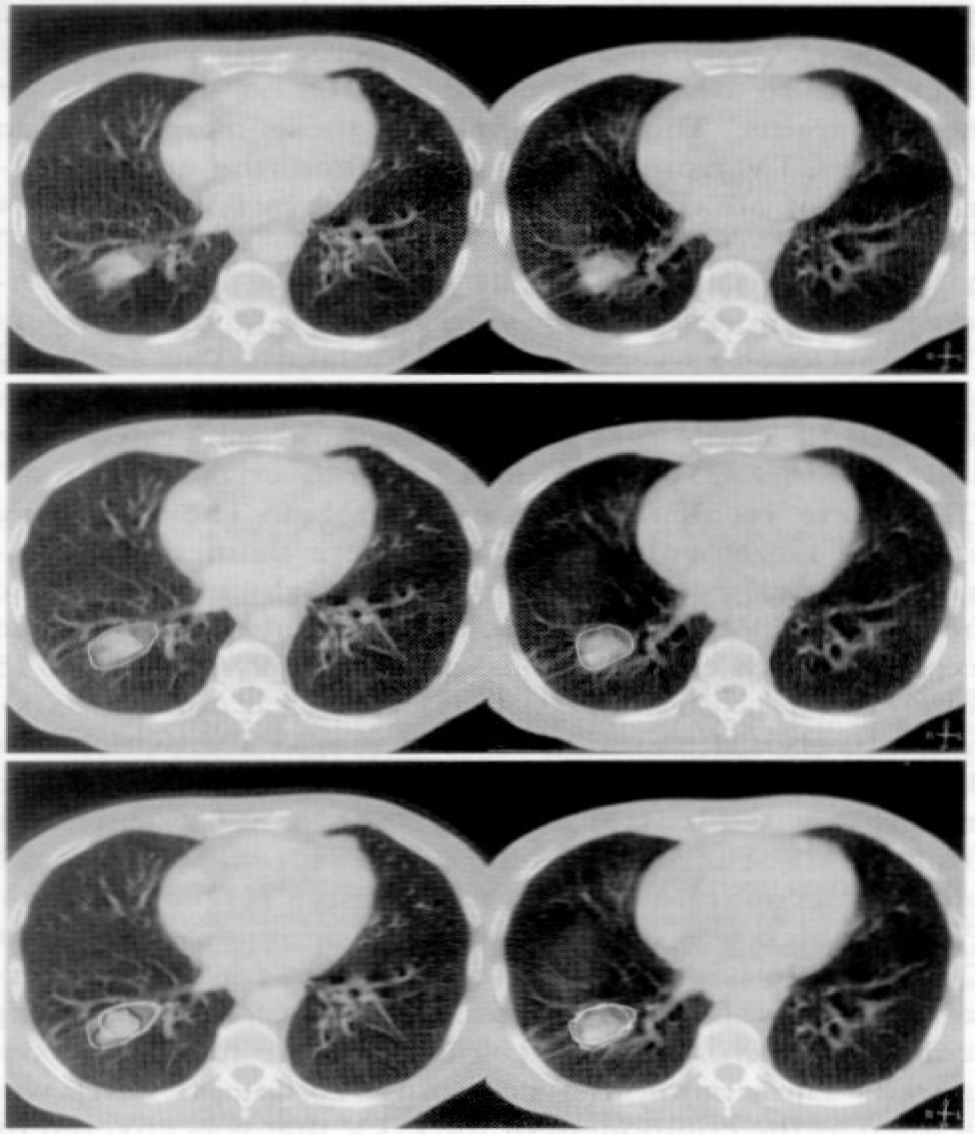
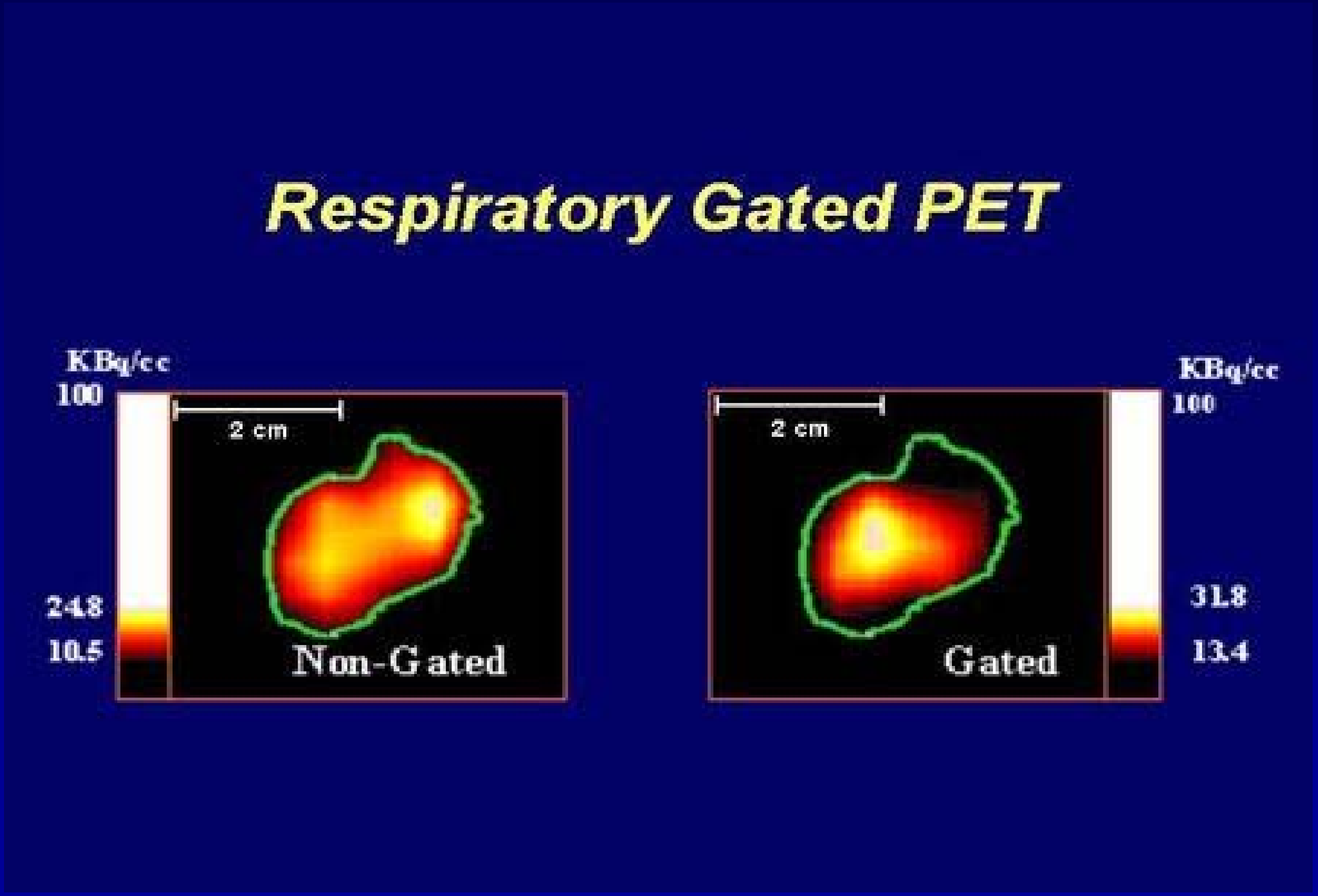


Fig. 1. Upper panel: Coregistered rapid (left) and slow CT scans (right). Blurring of the edges of mobile structures such as vessels and the heart are obvious on the slow scan. Middle panel: CT scans showing the corresponding contoured GTVs. Lower panel: Projection of all contoured GTVs on each type of scan.

RAPID AND SLOW CT SCAN OF THE CHEST CAN GIVE A DIFFERENT REPRESENTATION OF CTV SHAPE AND SIZE

“OPTIMAL” PTV OBTAINED BY CO – REGISTRATION OF 6 “FAST” CT SCAN

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS UNCERTAINTIES IN DEFINING CTV



RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN DEFINING CTV

ABSOLUTE AND RELATIVE CTVs FOR 7 PTS DERIVED USING RAPID AND SLOW SPIRAL CT SCANS

	A	B	C	D	E	F	G
Rapid CT*							
Mean CTV (cc)	191,7	22,7	17,5	17,0	37,2	75,8	25,0
Slow CT**							
Mean CTV (cc)	198,9	23,4	18,7	20,0	43,3	86,4	29,9

- 1 sec/rot; ** 4 sec/rot

da: van Sornsen de Koste, IJROBP, 2003

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN DEFINING CTV

ABSOLUTE AND RELATIVE CTVs FOR 7 PTS DERIVED USING RAPID AND SLOW SPIRAL CT SCAN

	A	B	C	D	E	F	G
CTV fast / CTV slow	96%	97%	94%	85%	86%	88%	84%
Targ.Cov (95% dose) CTV fast +5 mm/ CTV slow	100	99,9	88,9	97,9	99,4	97,6	99,4

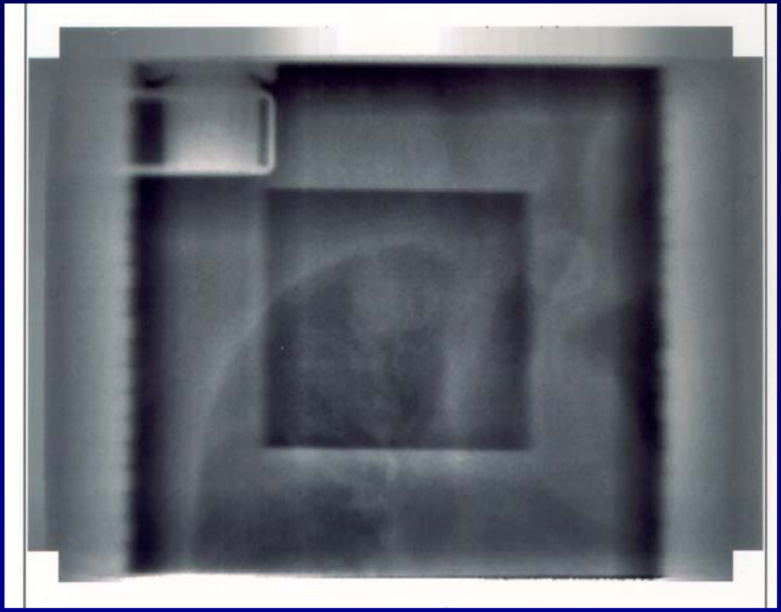
da: van Sornsen de Koste, IJROBP, 2003

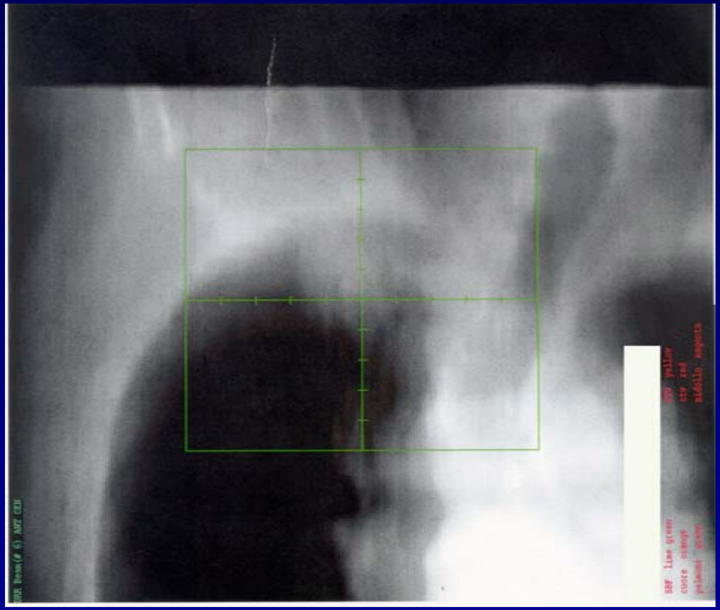
RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS : UNCERTAINTIES IN DEFINING CTV

- **GEOMETRICAL ERRORS DUE TO TUMOR MOBILITY HAVE BEEN POSTULATED TO BE AN IMPORTANT CAUSE OF LOCAL FAILURE IN LUNG CANCER EVEN WHEN 3 D PLANNING IS USED**

- **AS SINGLE NON GATED RAPID CT SCANS ARE COMMONLY USED FOR TREATMENT PLANNING, TUMORS MAY BE IMAGED IN NON REPRESENTATIVE POSITIONS WITHIN THE RESPIRATORY CYCLE, WITH CONSEQUENT SYSTEMATIC ERRORS IN TREATMENT PLANNING AND DELIVERY**

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV





2. Implicazioni nella fase di trattamento

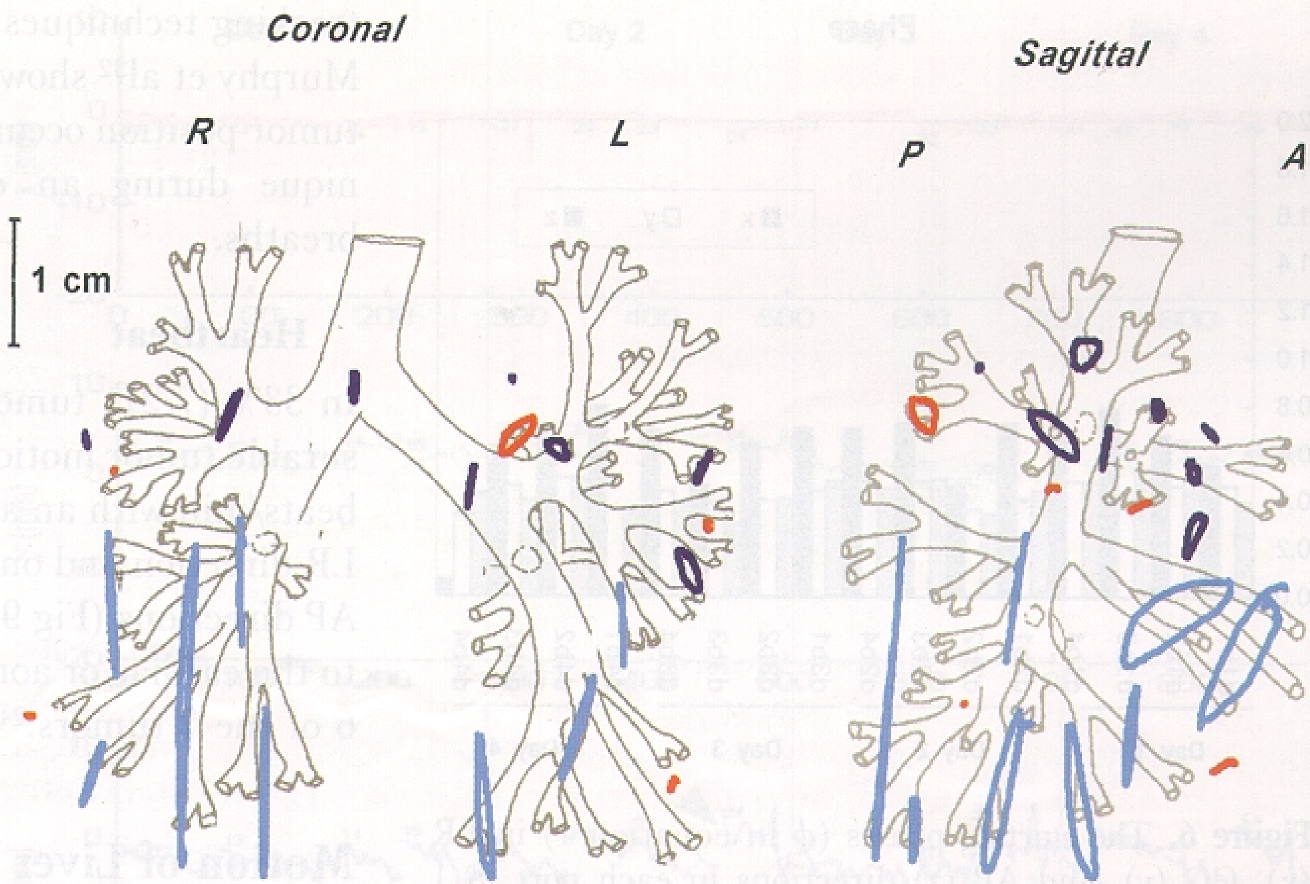
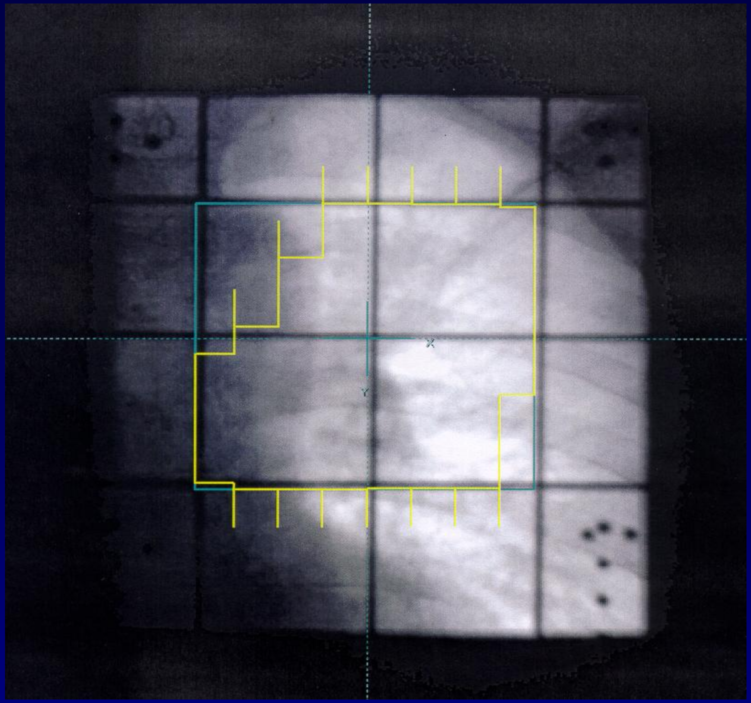
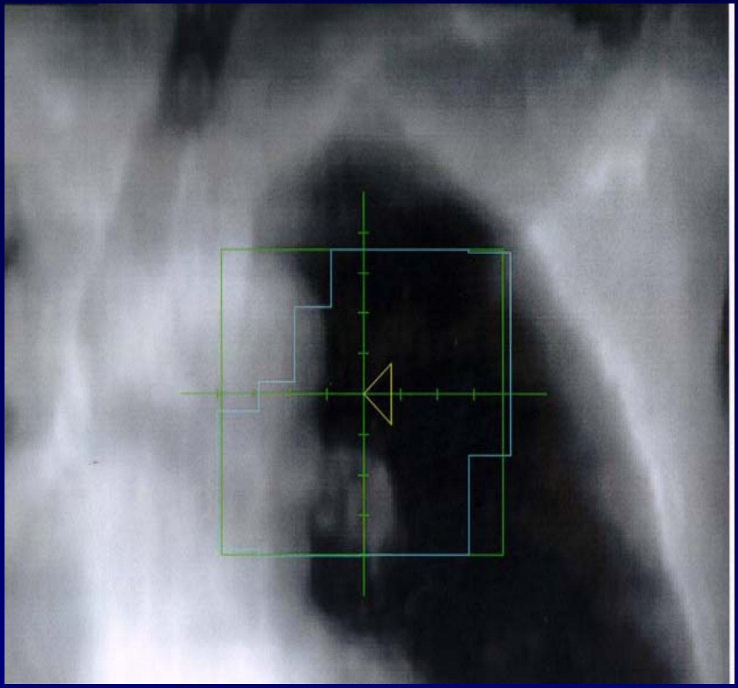


Figure 5. Orthogonal projections of the 3D trajectories of the 21 tumors on the coronal and the sagittal plane. The tumors are displayed at the approximate position. Tumors that were attached to bony structures are colored red; lower-lobe tumors are colored light blue. (Modified with permission.[24])

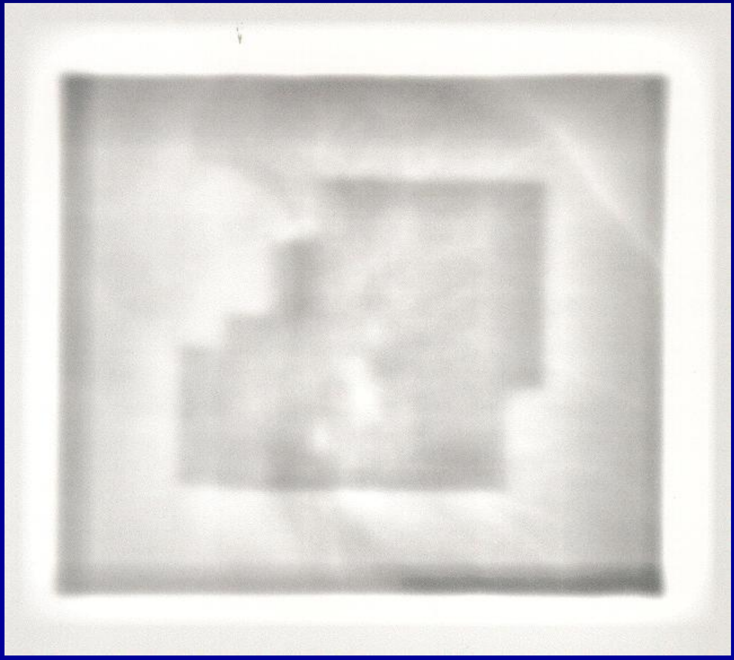
3D trajectories of 21 tumors in the coronal and sagittal plane

Lower lobe tumors are colored light blue





Necessità di margini adeguati a comprendere il CTV indipendentemente dalle escursioni respiratorie



RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV

How to limit motion?

- Abdominal compression
- Deep inspiration breathing training
- Active Breath Control
- Target tracking

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

How to limit motion?

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- Active Breath Control
- Target tracking

Controlled compression of of abdominal wall was emploied only when fluoroscopy showed a motion of the target of > +/- 7 mm

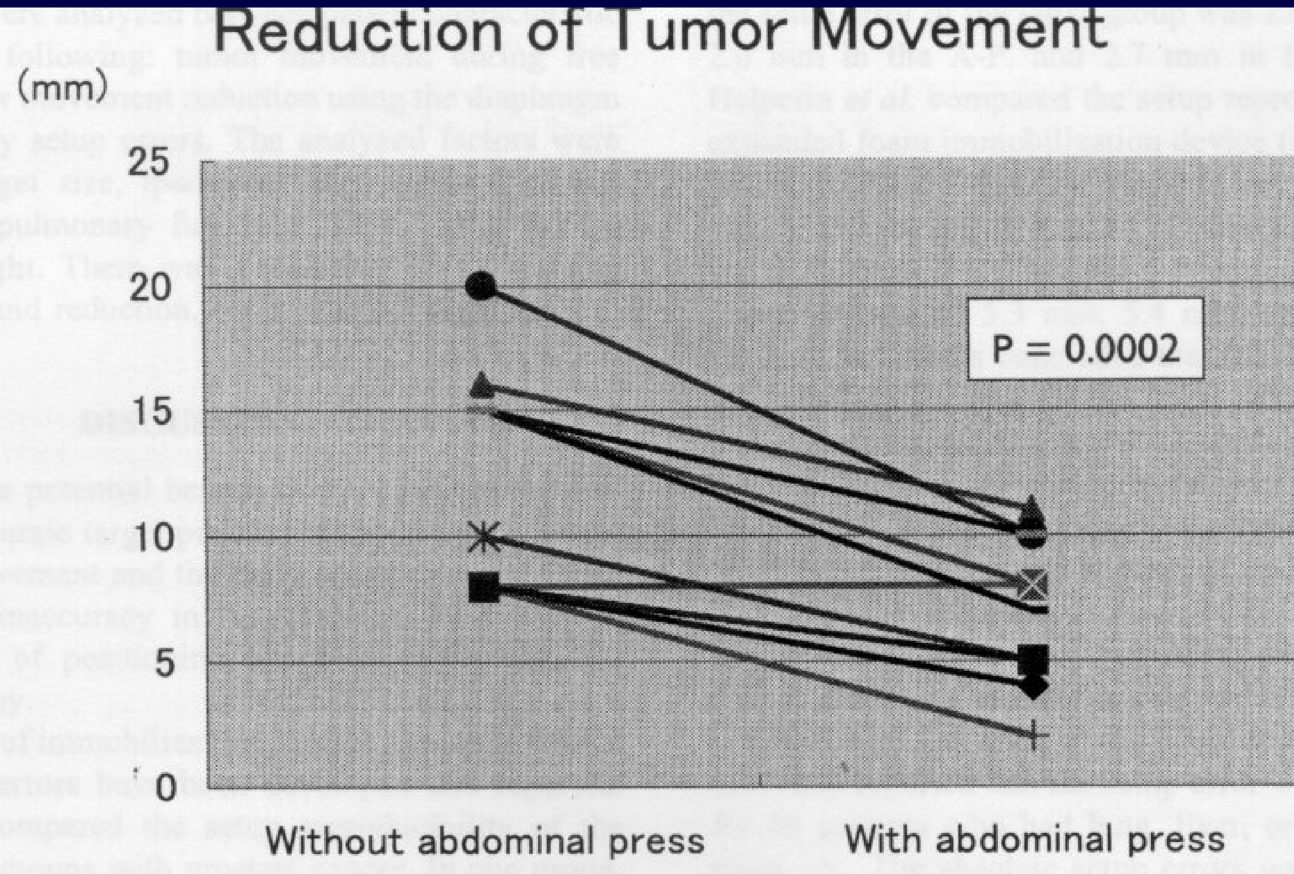

Fig. 6. Reduction of respiratory tumor movement by pressing patient's abdomen using the diaphragm control. The diaphragm control was applied to the patients whose tumor movement was 8 mm or more during free respiration. Tumor movements were reduced significantly ($p = 0.0002$).

From: Negoro, Y., IJROBP, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

Patient	Without abdominal compression (mm)	With abdominal compression (mm)
A	20.0	10.0
B	16.0	11.0
C	15.0	10.0
D	15.0	8.0
E	15.0	7.0
F	10.0	5.0
G	7.0	5.0

From: Negoro, Y., IJROBP, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

How to limit motion?

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- Target tracking

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV
Deep inspiration breathing training

- Deep inspiration breath holding: most reproducible position

- Increased lung volume: lower percentage of total lung volume receiving > 20 Gy

- Decreased lung density

- Tumor imobilization: PTV margin reduction

Barnes, EA et al : Int J Radiat Oncol Biol Phys, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

Supero inferior motion during free breathing (FB) or deep inspiration breath holding (DIBH)

Patient	Tumor location	FB SI motion (mm)	DIBH SI motion (mm)
A	RLL	31,9	1,4
B	RLL	22,5	3,8
C	Mediastinum	2,0	1,0
D	RUL	7,1	3,5
E	LLL	9,4	2,2
F	RML	10,0	2,5
G	LLL	10,0	2,1
H	RML	10,7	3,3
Mean		12,9	2,8

Barnes EA, et al: Int J Radiat Oncol Biol Phys, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

V 20 variations

Patient	Free breathing + margins	DIBH + margins	Decrease in V > 20 Gy (%)
A	13.9	5.2	62.6
B	19.5	11.0	43.6
C	14.5	14.7	- 1.4
D	11.7	7.6	35.0
E	16.8	15.5	7.7
F	13.3	8.4	36.8
G	6.3	4.5	28.6
H	6.0	3.2	46.7
Mean	12.8	8.8	32.5

Barnes EA, et al: Int J Radiat Oncol Biol Phys, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV
Deep inspiration breathing training

- Self gating at DIBH is an inexpensive, easily performed method of reducing the total lung volume receiving high dose irradiation

- The dosimetric benefit is patient specific and due to both the increased lung volume achieved at deep inspiration and the PTV margin reduction allowed through tumor imobilization

- Not all patients are suitable for this technique

Barnes, EA et al : Int J Radiat Oncol Biol Phys, 2001

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV

How to limit motion?

- Abdominal compression
- Deep inspiration breathing training
- Active Breath Control
- Target tracking

Active breath control

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV
Active breath control

- The patient's breathing is monitorized continuously
- At a preset lung volume airflow of the patient is temporarily blocked immobilizing breathing motion
- The duration of the active breath hold is that which is comfortably mantained by each patient
- Radiation will be turned on and off during this period

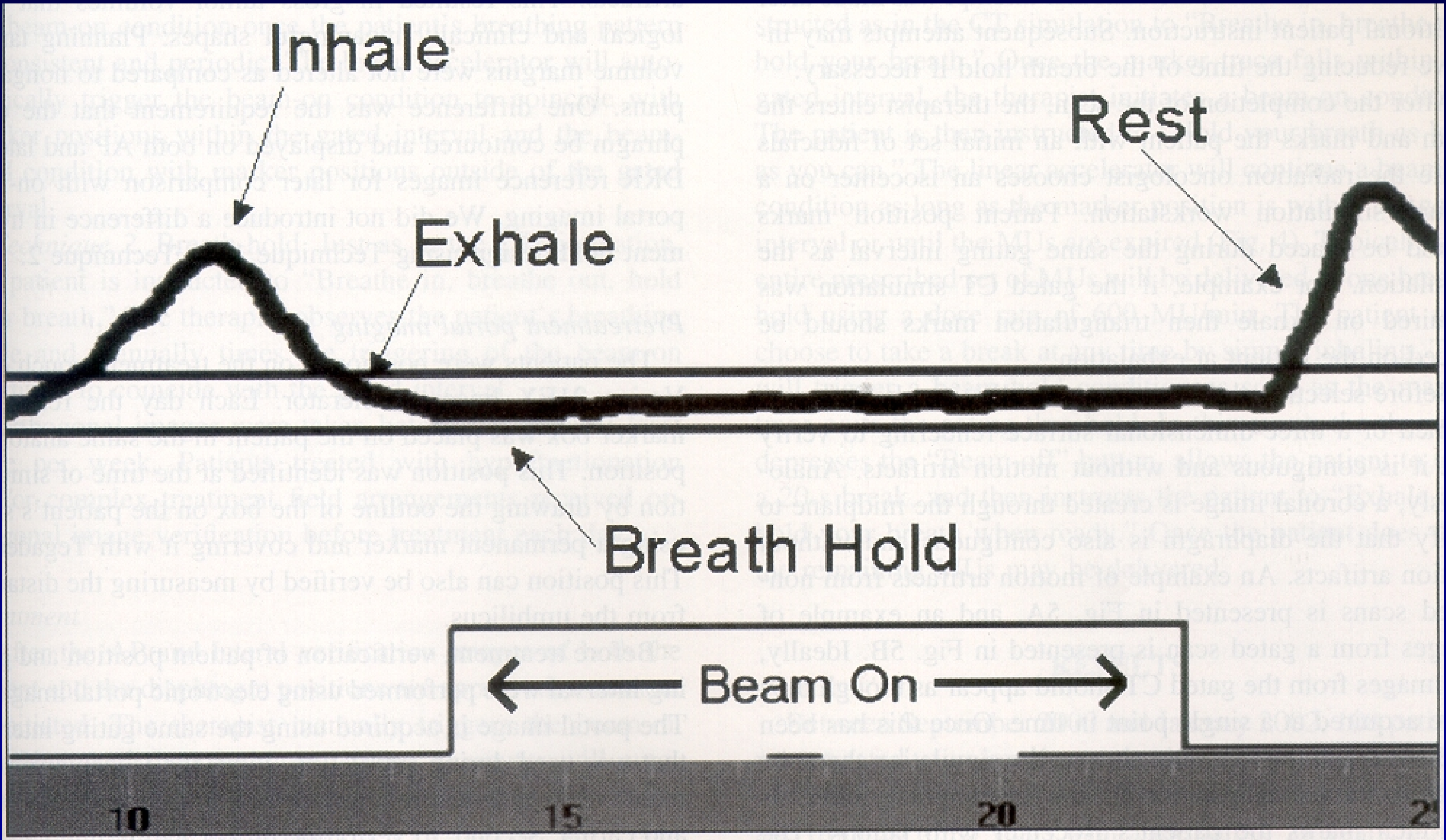
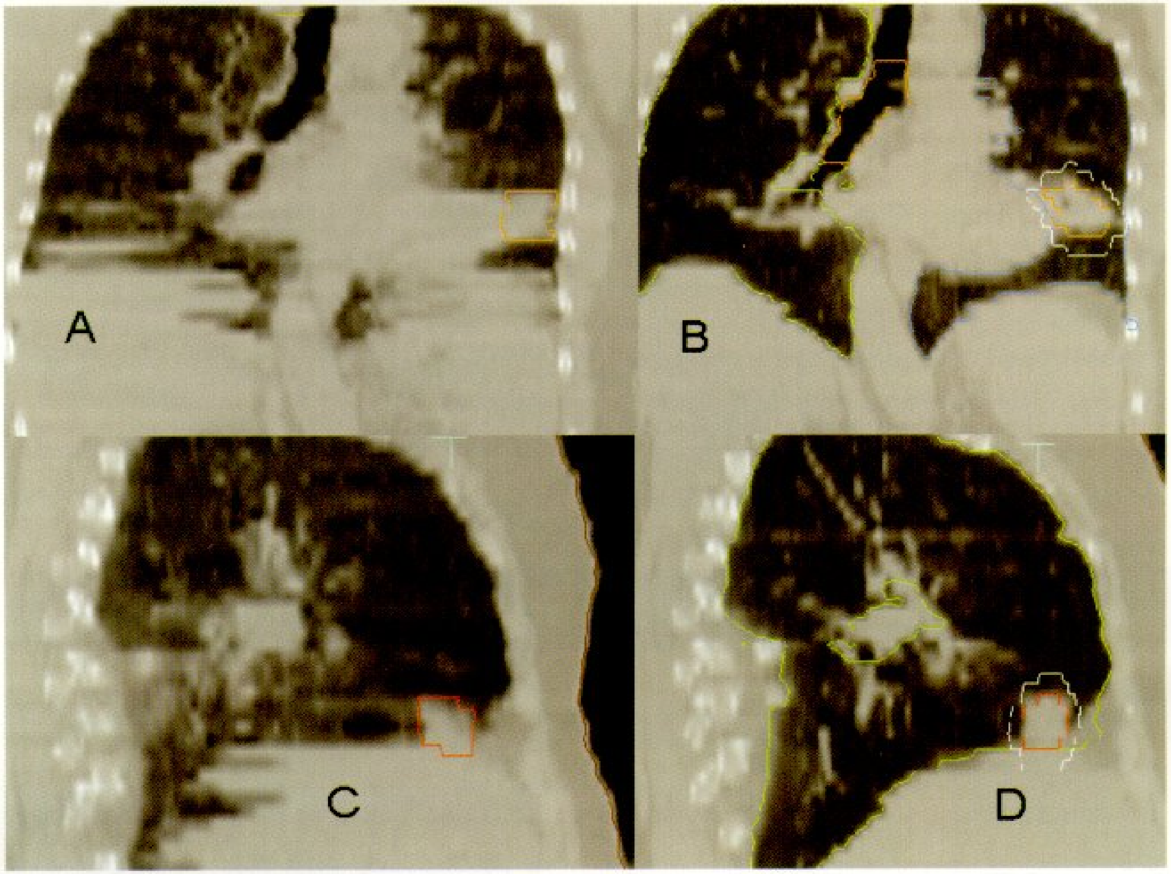


Fig. 4. Part of the respiratory gating software user interface. The wave represents the patient's respiration during a breath hold on exhalation. The beam-on condition corresponds to the amplitude-gated exhalation.



Coronal and sagittal views demonstrating the difference between simulation CT scans obtained during free-breathing and scans obtained using Elekta's Active Breathing Coordinator.™ A: coronal reconstruction of scans obtained during free-breathing from a patient with a left lung tumor; B: same view of same patient, reconstructed from a scan obtained with the use of Active Breathing Coordinator.™ Note the highly irregular contour of the diaphragm and poorly defined tumor borders in the free-breathing scan, a result of respiratory excursion during scan acquisition. C and D: similar comparisons of free-breathing and Active Breathing Coordinator™-controlled scans, in a sagittal view of a patient with a right-sided lung tumor. Active Breathing Coordinator™ provides a much smoother diaphragm contour in the reconstruction and greater confidence in tumor localization and size determination.

CORONAL AND SAGITTAL VIEWS DEMOSTRATING THE DIFFERENCES BEETWEEN CT SCANS OBTAINED DURING FREE BREATHING (A AND C) AND SCANS OBTAINED WITH AN ACTIVE BREATHING CONTROL DEVICE (B AND D).

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN TARGETING PTV

Active breath control

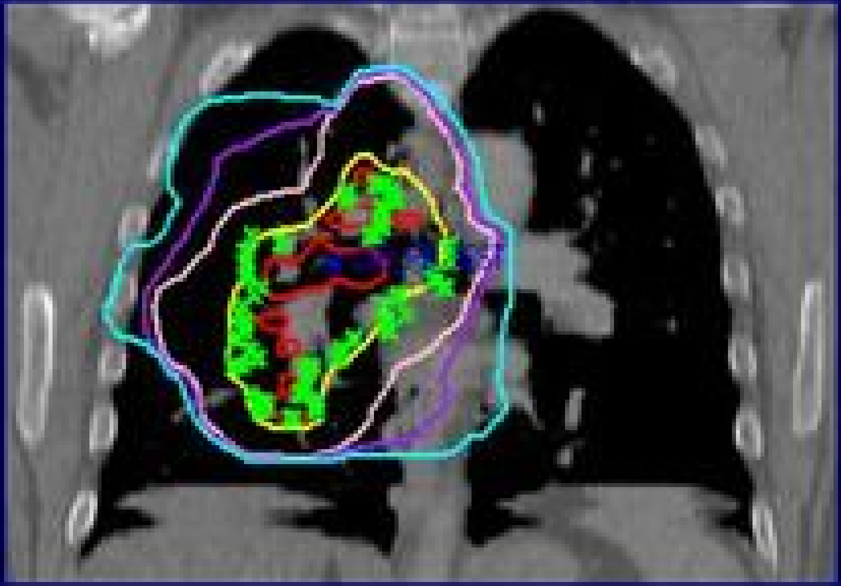
Average excursions beetween edge profiles of 2 ABC CT scan

Region	n Data points	Intrafraction (mm)	Interfraction (mm)
Diaphragm	60	1.5+/-1.8	4.0+/-3.3
Mid thorax	20	2.1+/-1.7	3.9+/-3.1
Apex	36	2.6+/-2.0	2.0+/-2.2

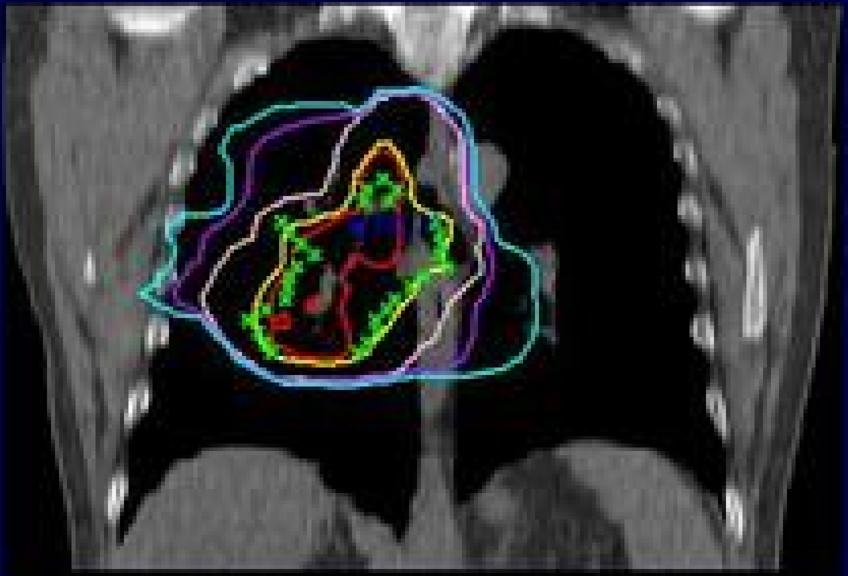
Wong, JW: Int J Radiat Oncol Biol Phys, 1999

Comparison of Free Breathing and Respiratory Gated Treatment Plans

Free breathing



Gated - inspiration



- Less lung within the radiation field with gating on inspiration
- NTCP decreased from 30% to 19% with gating technique

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

How to limit motion?

- Abdominal compression
- Deep inspiration breathing training
- Active Breath Control
- Target tracking

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS: UNCERTAINTIES IN TARGETING PTV

Real time tumor tracking (RTRT): automatic repositioning of the beam relative to the tumor target

- **Shift the patient using a remotely controlled couch**
- **Shift the beam by physically repositioning the radiation source (CyberKnife)**
- **Redirect the beam electromagnetically (for charged particle beams)**
- **Shift the aperture of a remotely controlled colimator**
- **Gating the beam to tumor motion**

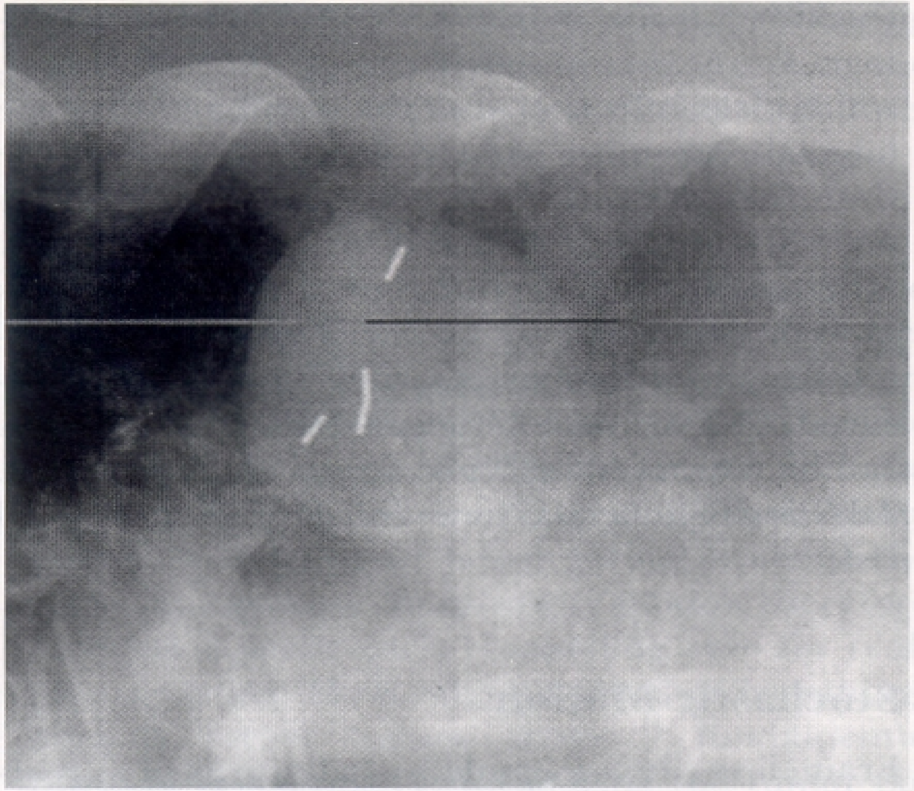


Figure 1. A radiographic image of a lung tumor containing 4 gold fiducials, taken with a real-time amorphous silicon imaging system during a CyberKnife lung radiosurgery treatment.

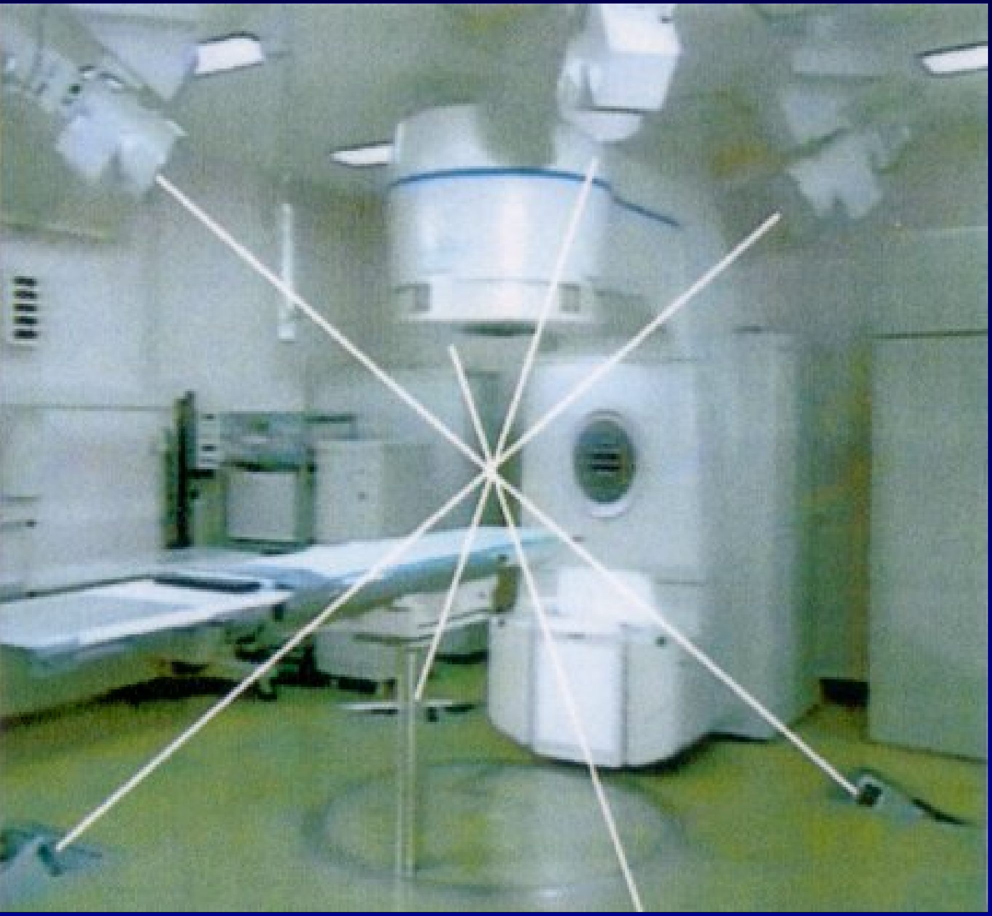
4 ways to locate the target:

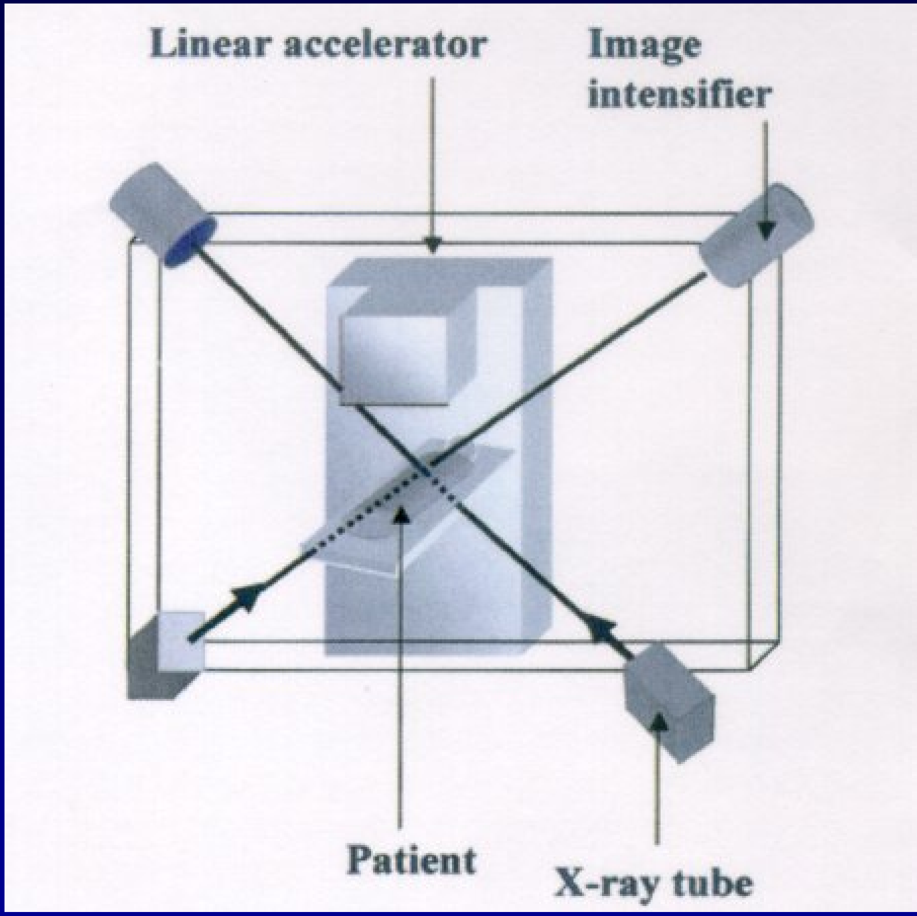
- Image the tumor
- Image anatomical structures rigidly connected to the tumor
- Detect artificial fiducials implanted in the tumor
- Track surrogate organs that move in synchrony with the tumor

Tumor motion measured via radiographic imaging

Measure the target position on a time scale faster than the motion itself

Fiducial based guidance has the advantage that the fiducials are easily located with automatic image processing tools and the time needed to make a position determination is short (50 msec)





Determination of 3D coordinates of tumor markers by mean of fluoroscopic digitized images

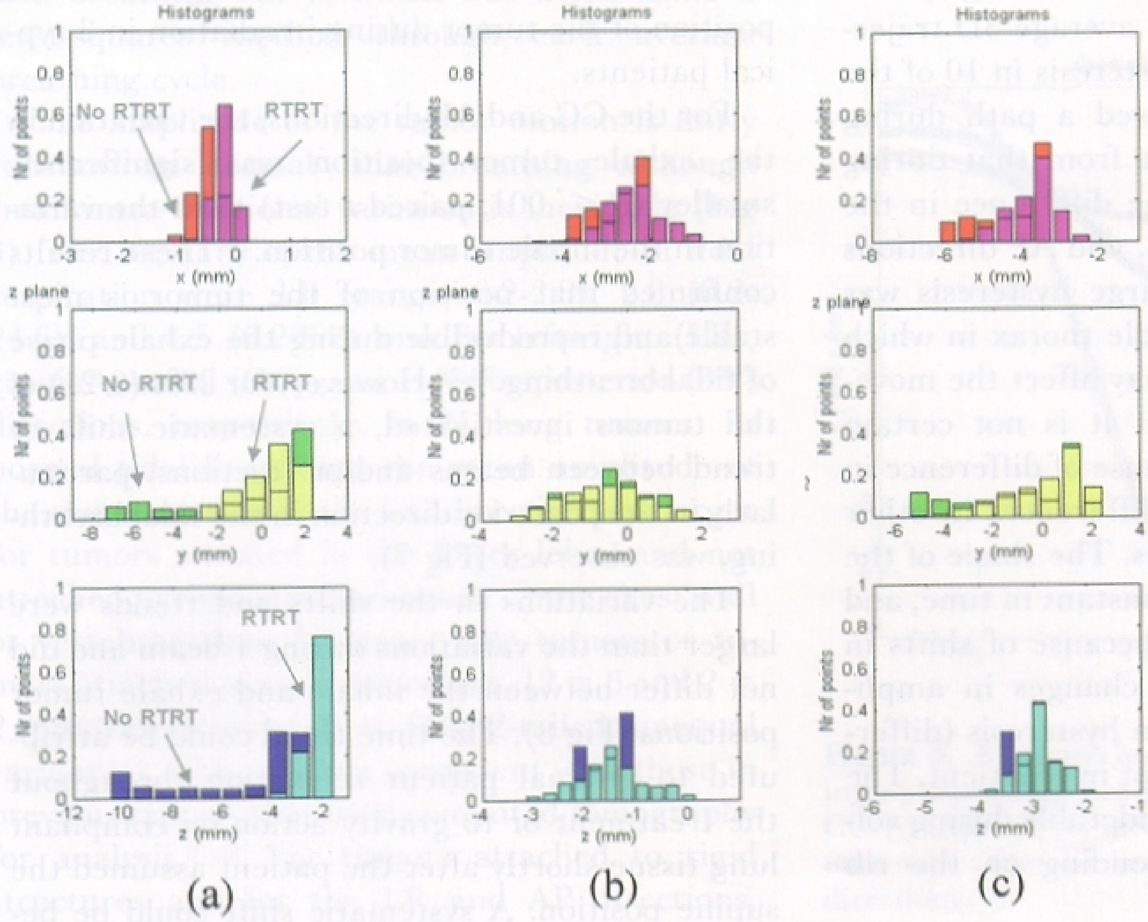


Figure 7. Histograms of the position of the tumor during irradiation for 3 typical lung tumors. (A-C) Three different tumors in 3 corresponding patients. RTRT represents the histogram of the position of the tumor when therapeutic beam was on using RTRT system. No RTRT represents the histogram of the position of the tumor when therapeutic beam was off using RTRT system.

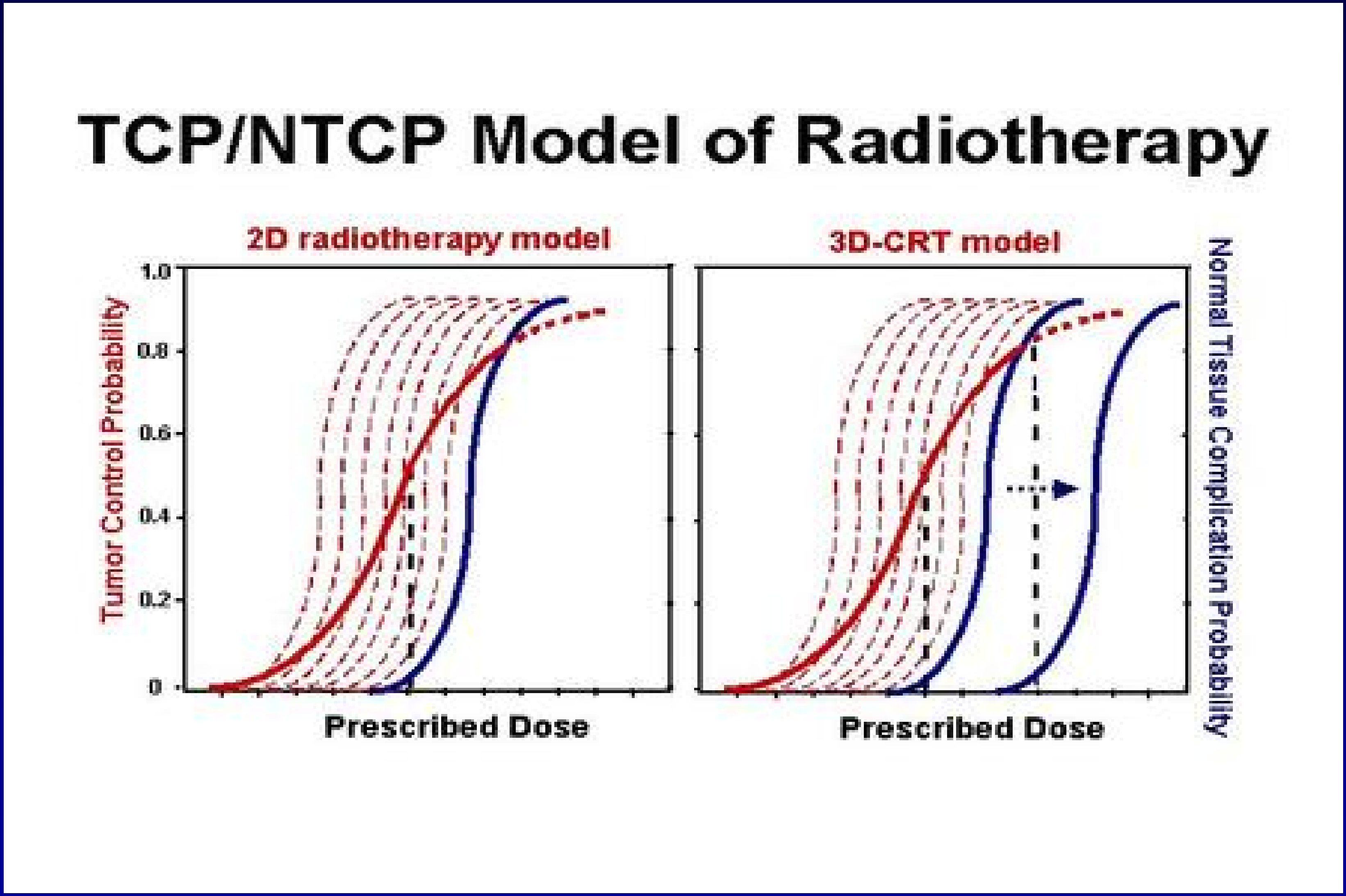
Real time tumor tracking: gating the beam to target motion. If the 3D coordinates of tumor markers are within predetermined limits the system allows the Linac to irradiate the patient

Shirato, H: Sem Radiat Oncol, 2004

Interventions to reduce organ motion effects in radiation planning and treatment of lung cancer

Conclusions

- Methods of reducing the adverse effect of organ motion occurring during a radiation treatment of lung tumors are many (abdominal compression, treating during voluntary or controlled breath hold, tracking radiation with tumor motion)
- Interventions to reduce organ motion must be patient specific, with individual studies of organ motion and reproducibility of intervention
- Reduction of organ motion must ensure an adequate representation of CTV extension during planning procedures
- Reproducibility of organ position must be good enough to permit a reduction in PTV margins



REDUCTION OF RESPIRATORY MOVEMENTS CAN REDUCE THE DOSE TO CRITICAL ORGANS SHIFTING NTCP CURVE TO THE RIGHT ALLOOWING DOSE ESCALATION WITHOUT INCREASING THE RISK OF LATE COMPLICATIONS

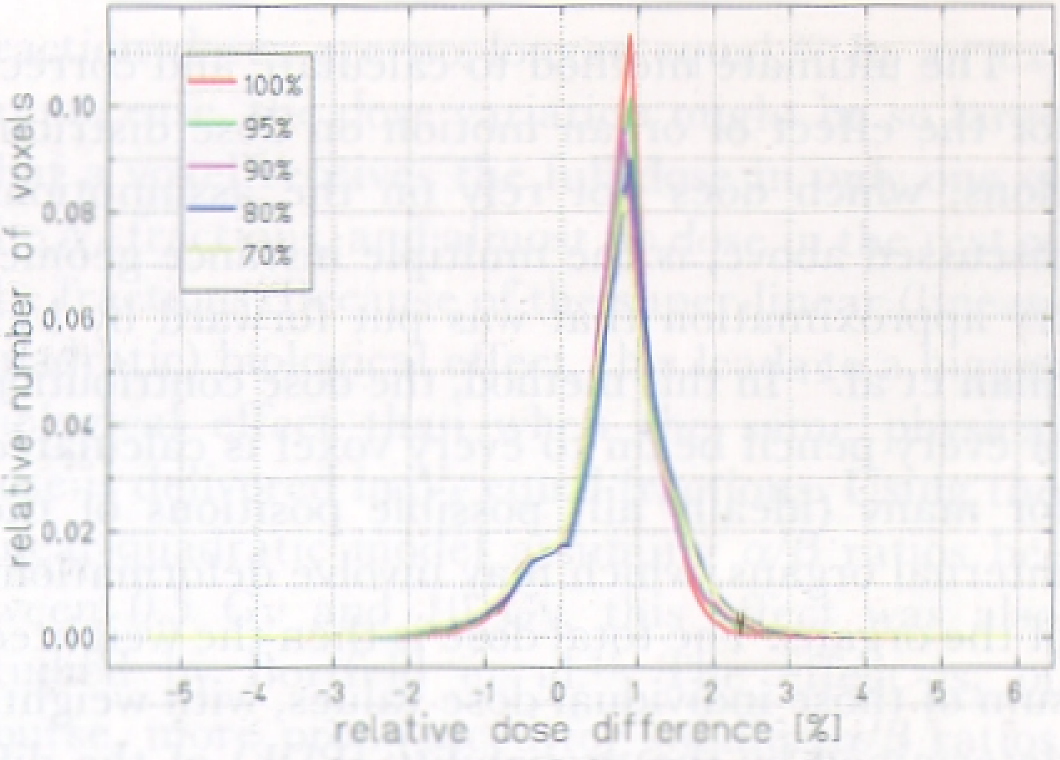


Figure 10. Histograms of the relative differences between the dose distributions recalculated with the same treatment plan based on CT data close to the inhale and close to the exhale breathing phases of the patient. The differences are shown for different ranges of isodose levels of the inhale dose distribution: 70%, max dose yellow; 80%, max dose blue; 90%, max dose magenta; 95%, max dose green; and 100%, max dose red.

Table 1. Effects of total radiation dose on local progression-free survival*

Dose	Local progression-free survival (%)		
	12 months	24 months	30 months
65 Gy	53	26	26
75 Gy	81	61	38
Projected dose for 50% LPFS	64 Gy	72 Gy	85 Gy

* Martel *et al.* (16).

LPFS = Local progression-free survival.

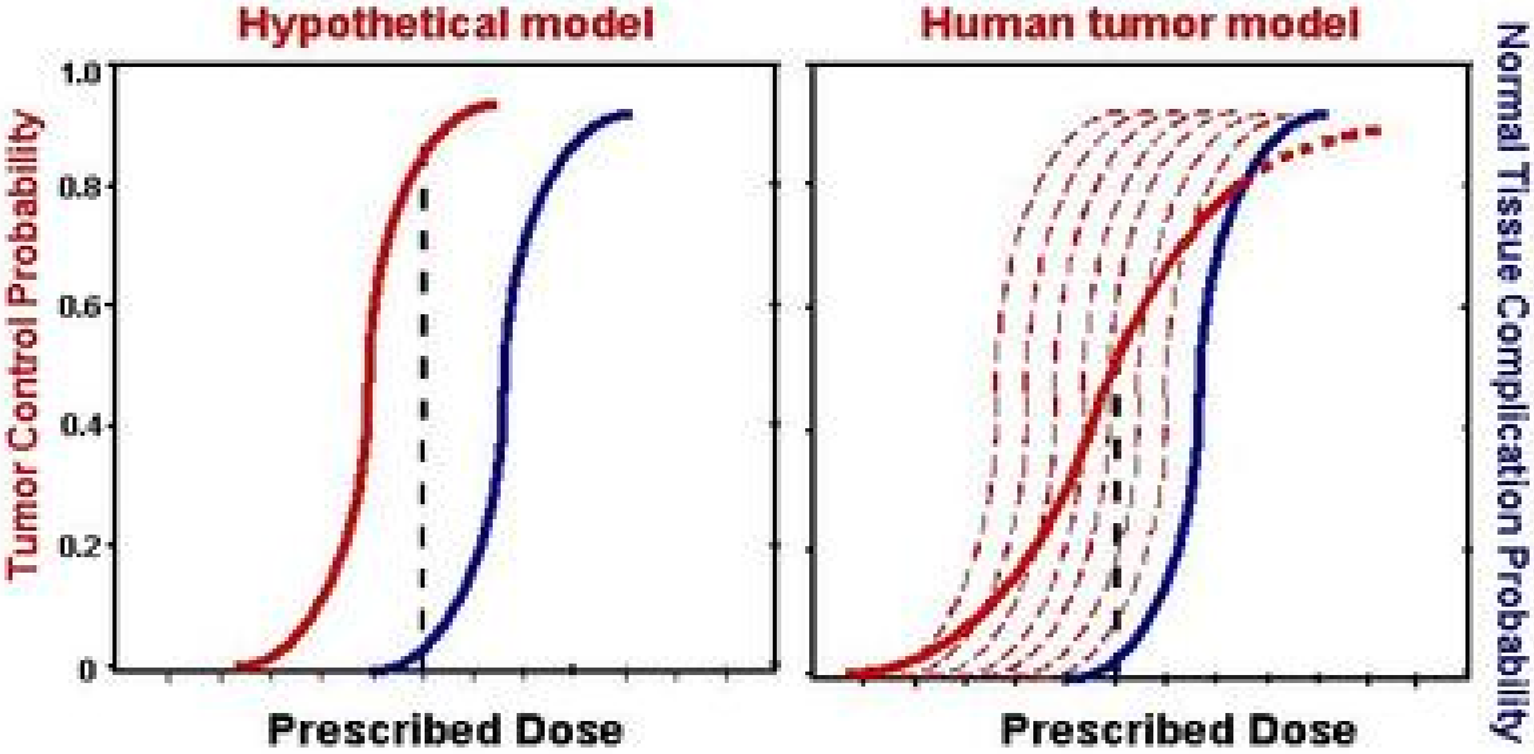
Non-Small Cell Lung Cancer
3D-CRT Dose-Escalation Study

Results of 64 patients treated to protocol dose

Dose (Gy)	No. Pts	Acute/Late Lung Toxicity	F/U (mo)	2-year Overall Survival	2-year Local Control
70.2+ ENI	14	3/2	14	21%	31%
70.2	11	1/0	14	27%	30%
75.6	10	1/0	18	33%	39%
81	11	1/0	20	50%	52%
84 Stage II/III	10	0/0	4	75%	89%
90 Stage I	8	1/0	6	100%	100%

MSK,2000

TCP/NTCP Model of Radiotherapy

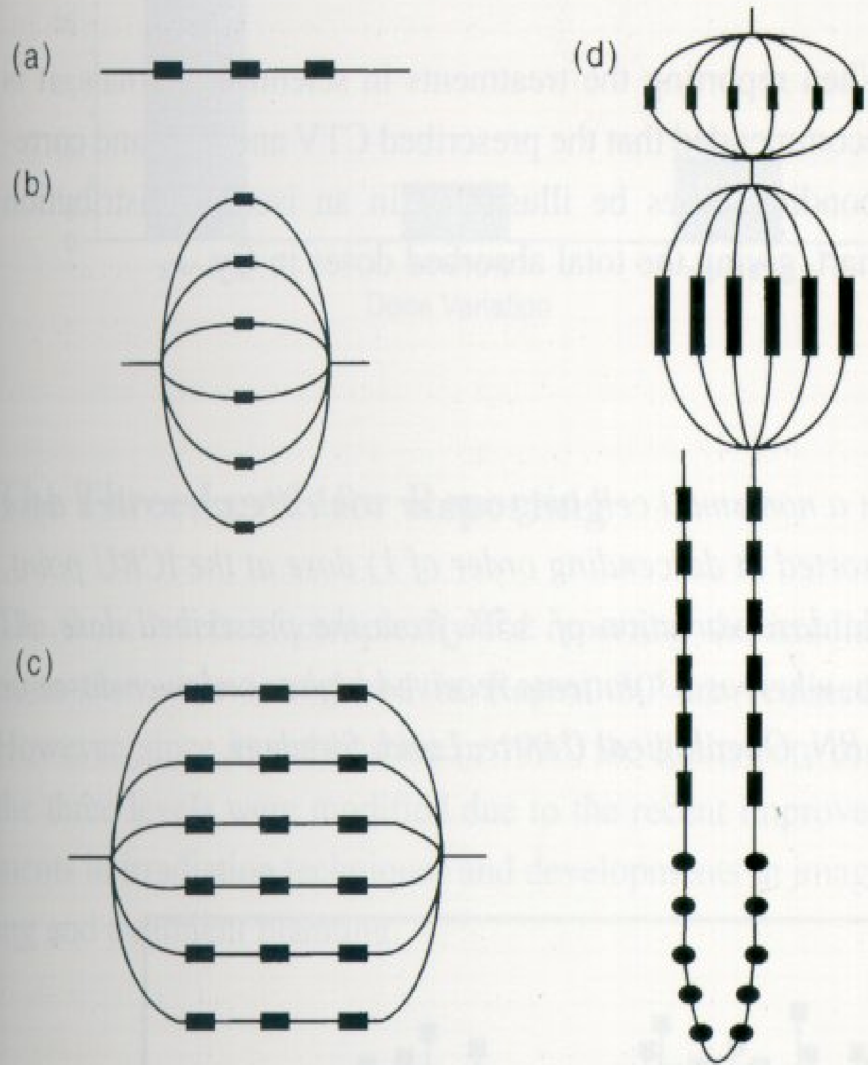


The Paradigm of Three-Dimensional Conformal Radiotherapy (3D-CRT)

- New computer algorithms enable detailed 3D dose calculations for the total volume irradiated
- Computer-aided treatment planning targets prescribed dose to the tumor with high precision
- Targeting the high dose to the tumor reduces normal tissue exposure
- Reduced normal tissue exposure decreases toxicity and permits a safe increase of tumor dose

Shift of normal tissue complication curve to the high dose region is possible only in tissues that exhibit a strong volume effect

Figure 4. *Schematic examples of tissue organization structures in the parallel-serial model.*



a) a serial string of subunits
(*e.g.*, the spinal cord),

b) a parallel string of subunits
(*e.g.*, the lungs),

c) a serial-parallel string of subunits
(*e.g.*, the heart),

d) a combination of parallel and serial structures
(*e.g.*, a nephron)

(Modified from Withers et al., (1988) and Källman et al., (1992))

How is the 3D-CRT paradigm applied in clinical practice?

Tools Required for Planning and Delivery of Conformal Radiotherapy

- CT simulators for 3D delineation of tumor and normal tissues
- New algorithms for dose calculations
- Advanced treatment planning systems
- Computerized optimization of treatment plans
- Computer-driven multileaf collimators
- Immobilization devices and on-line portal imaging

PTV (ICRU Report 62)

La distribuzione di dose all'interno del PTV viene rappresentata in maniera statica e non tiene conto delle incertezze di posizione , di dimensioni e della relazione tra fasci e sistema di coordinate. Se il margine del PTV non è adeguato alcuni tessuti, possono per parte del trattamento, essere più o meno compresi nel fascio terapeutico (sovra o sottodosaggi).

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TABLE 2.1—*Factors to be considered when defining a planning target volume*

Category	Intrafractional variations (Variations during a single fraction)		Interfractional variations (Variations during the entire course of treatment)	
	Random	Systematic	Random	Systematic
Variations of CTV				
In size	Physiological processes (circulation, respiration, peristalsis)	Physiological processes (circulation)	Physiological processes (*e.g.*, degree of bladder filling, bowel gas)	Tumor reduction or swelling
In position relative to a fixed point in the patient	Physiological processes (circulation, respiration, peristalsis)	Change in treatment position (prone-supine)	Physiological processes (*e.g.*, degree of filling of cavities)	Weight loss
Variations in position of the patient relative to the treatment beams	Patient movements		Daily set-up	Technical errors

Internal Margin (IM)

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CTV $\rightarrow$ ITV

per conpensare l'effetto di movimenti variazioni in dimensioni, forma e posizione degli organi e tessuti contenuti nel CTV durante il corso della terapia in relazione a un punto di riferimento interno: Internal Reference Point (IRP)

- **variazioni interne principalmente di tipo fisiologico**
- **non possono essere facilmente controllate e non dipendono dalle incertezze esterne nella geometria dei fasci**
- **possono dipendere dal set-up quotidiano del paziente.**

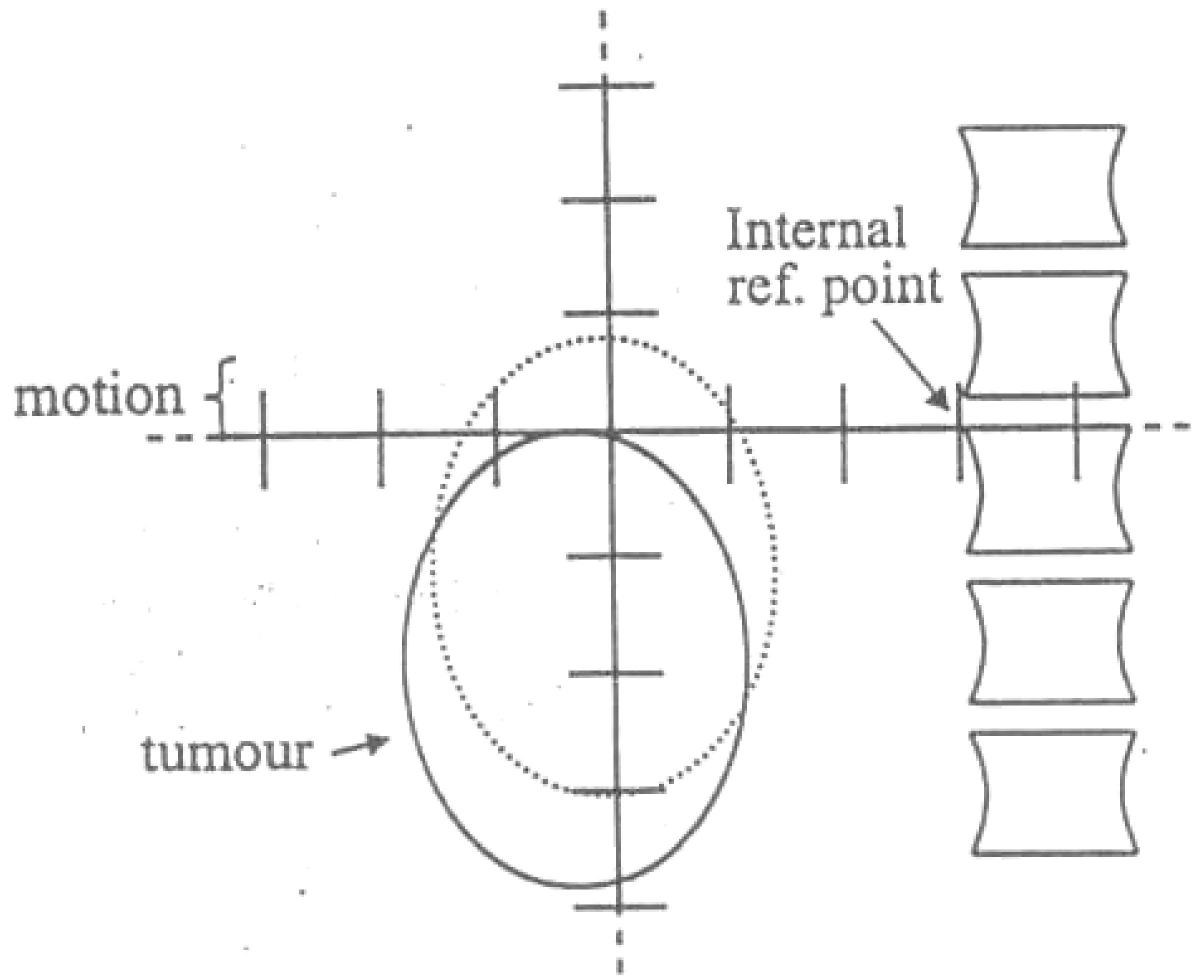


Fig. 1. Measurement of tumour movement. The simulator cross-line scale is used to measure the distance between the cranial tumour border in inspiration (unbroken line) and expiration (dotted line).

Movimento d'organo rispetto a un punto di riferimento interno

Set-Up Margin (SM)

ICRU Report 62

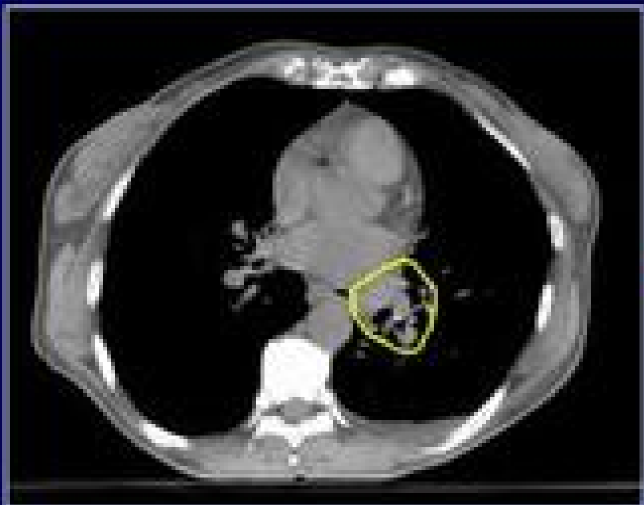
per tenere in conto specificatamente delle incertezze (inaccuratezze e difetto di riproducibilità nel posizionamento del paziente e nell'allineamento dei fasci terapeutici durante la pianificazione del trattamento e durante tutte le sessioni del trattamento in relazione a un punto di riferimento esterno)

nella scelta di un margine (CTV $\rightarrow$ PTV):

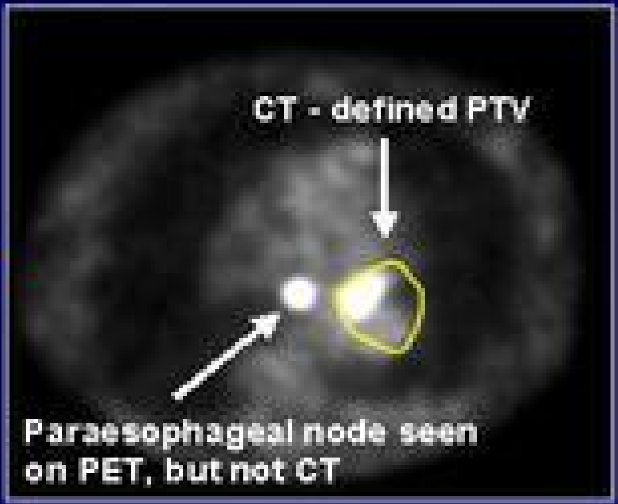
- deve ricercarsi un compromesso fra il rischio di complicazioni e il rischio di mancato controllo locale
- devono effettuarsi considerazioni di carattere statistico
- devono essere considerate le conseguenze delle variazioni geometriche sulla dose effettivamente depositata (es: avvalendosi di misure effettuate su pazienti reali)

Treatment Planning Using PET Imaging

CT simulation



FDG-PET scan

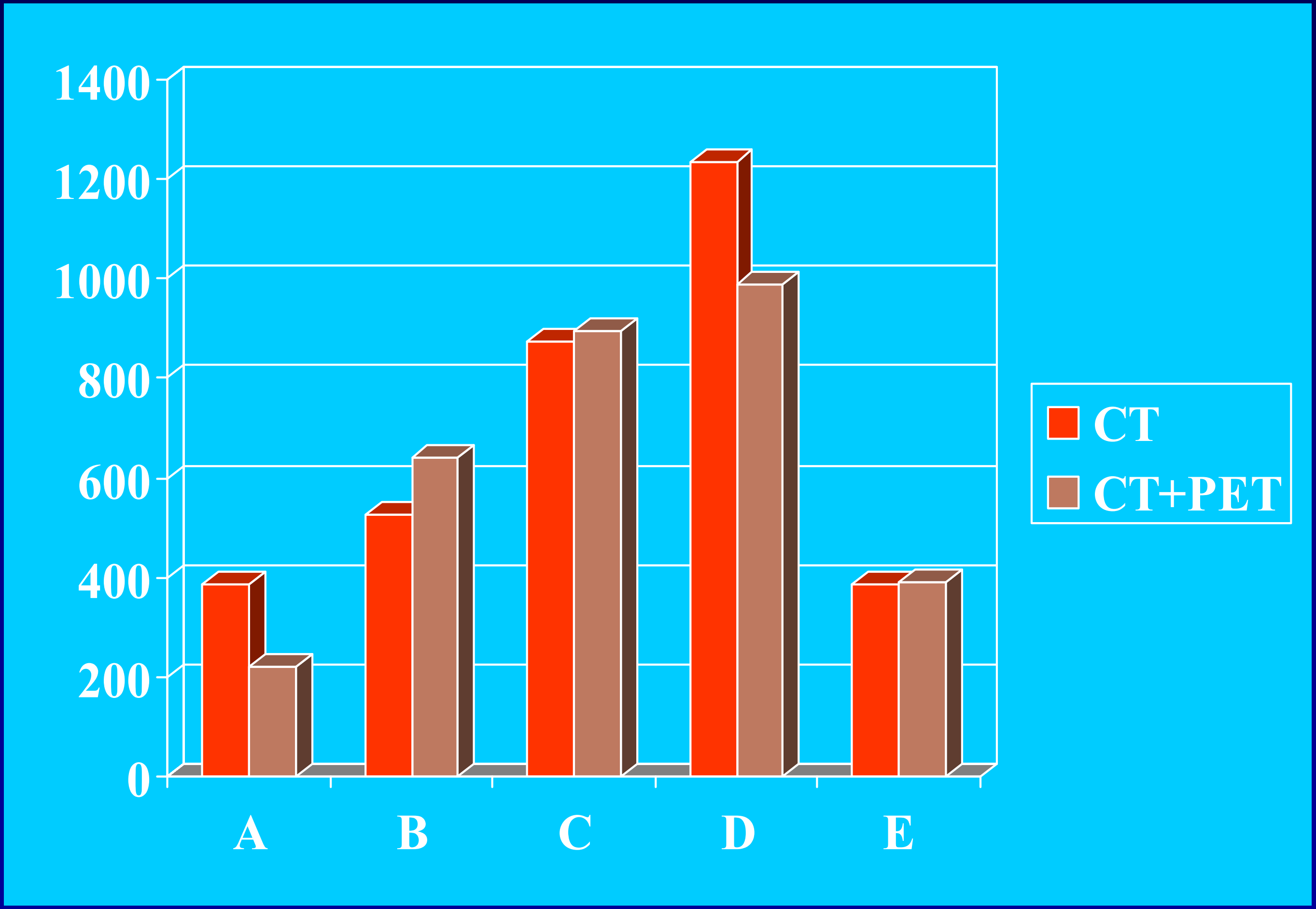


Register

Derive GTV - PTV

Treatment planning

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS UNCERTAINTIES IN DEFINING CTV



PTV volumes (cc) of 5 pts measured from CT and CT+PET data

From: Erdi, Radiother. Oncol., 2002 (modif)

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

- Allo scopo di ridurre il volume di tessuti sani irradiati, è indispensabile ridurre il “set-up margin” e l’”internal margin”.

- Vanno pertanto messe in atto strategie che consentono sia una maggiore riproducibilità del trattamento (riduzione del set up margin) che una riduzione dei movimenti respiratori, tanto nel corso dell’acquisizione delle immagini utilizzate per l’elaborazione del piano di trattamento (TC) che nel corso del trattamento stesso (riduzione dell’internal margin).

SET UP MARGIN

PROCESSO DI ANALISI

scopo:

- **comprendere l’effetto degli errori sistematici e casuali**
- **derivare i margini fra CTV e PTV**

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

Riduzione del set – up margin: sistemi di immobilizzazione

Deviazione standard di tutti gli errori di set up (in mm.)

	Expanded foam	T-bar
N. Totale misure	236	252
Deviazione standard	4.7	5.1

Halperin, IJROBP 1998

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

Riduzione del set – up margin: sistemi di immobilizzazione

Deviazione standard dell’errore di set up (in mm.)

	Expanded foam	T-bar
Antero – Posteriore	5.1	5.4
Longitudinale	5.1	3.6
Laterale	3.6	5.3

Halperin, IJROBP 1998

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

Riduzione del set – up margin: sistemi di immobilizzazione

Errore sistematico medio (in mm.)

	Expanded foam	T-bar
Antero – Posteriore	- 0.7	0.0
Longitudinale	0.2	0.4
Laterale	0.5	- 1.6

Halperin, IJROBP 1998

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

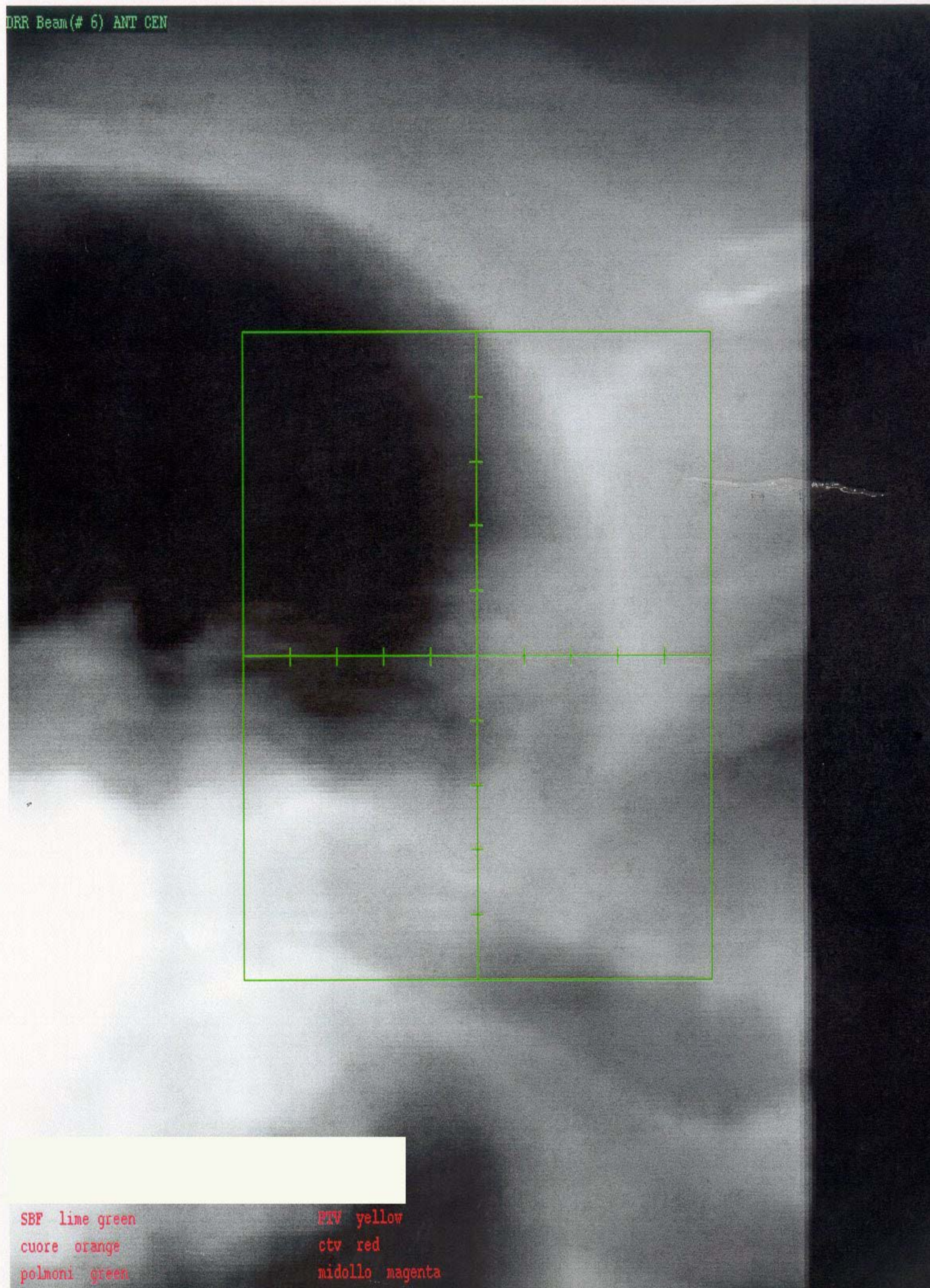
Riduzione del set – up margin: sistemi di immobilizzazione

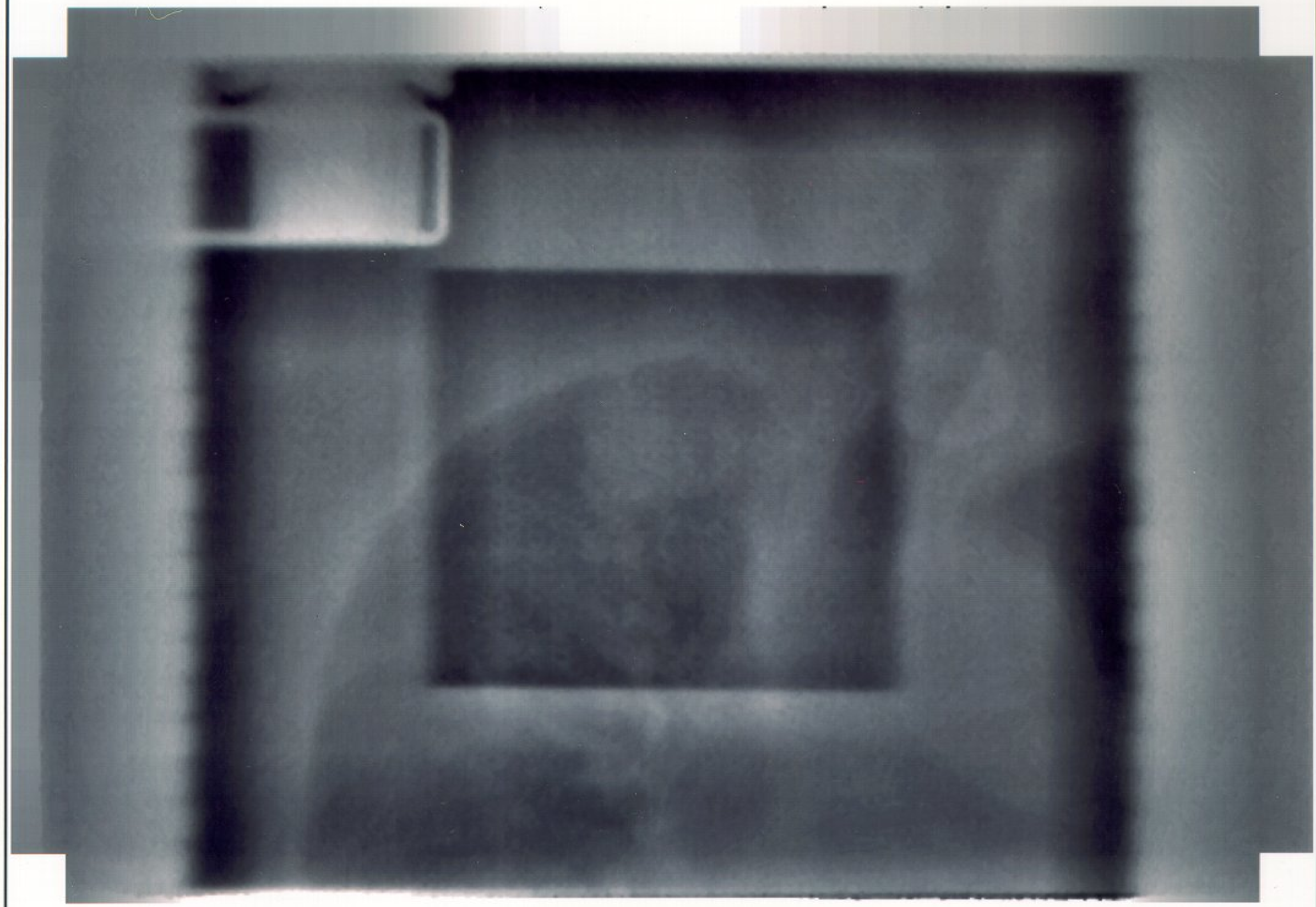
Sistema di immobilizzazione: braccio a T

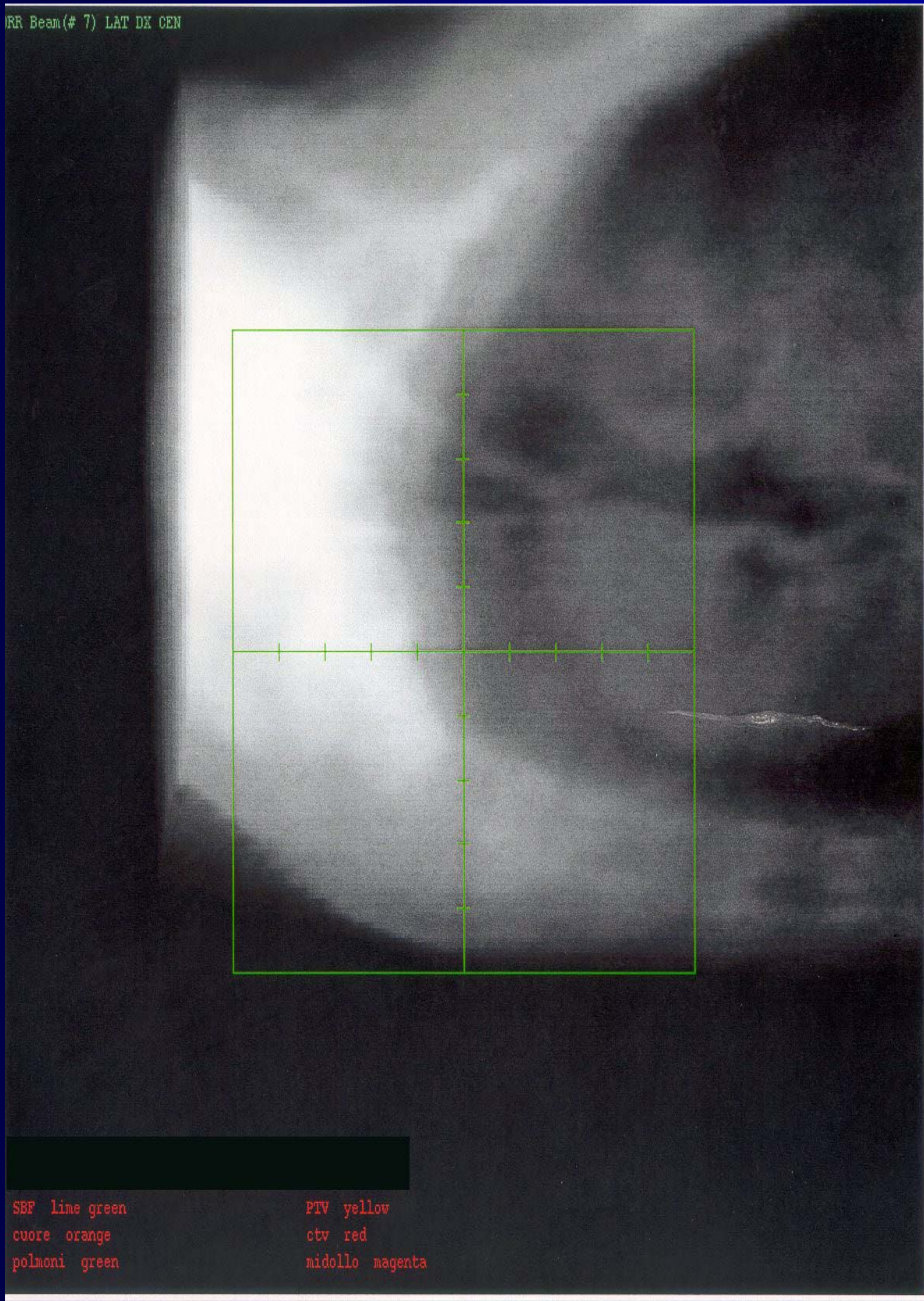
Deviazione standard dell'errore di set up (in mm.)

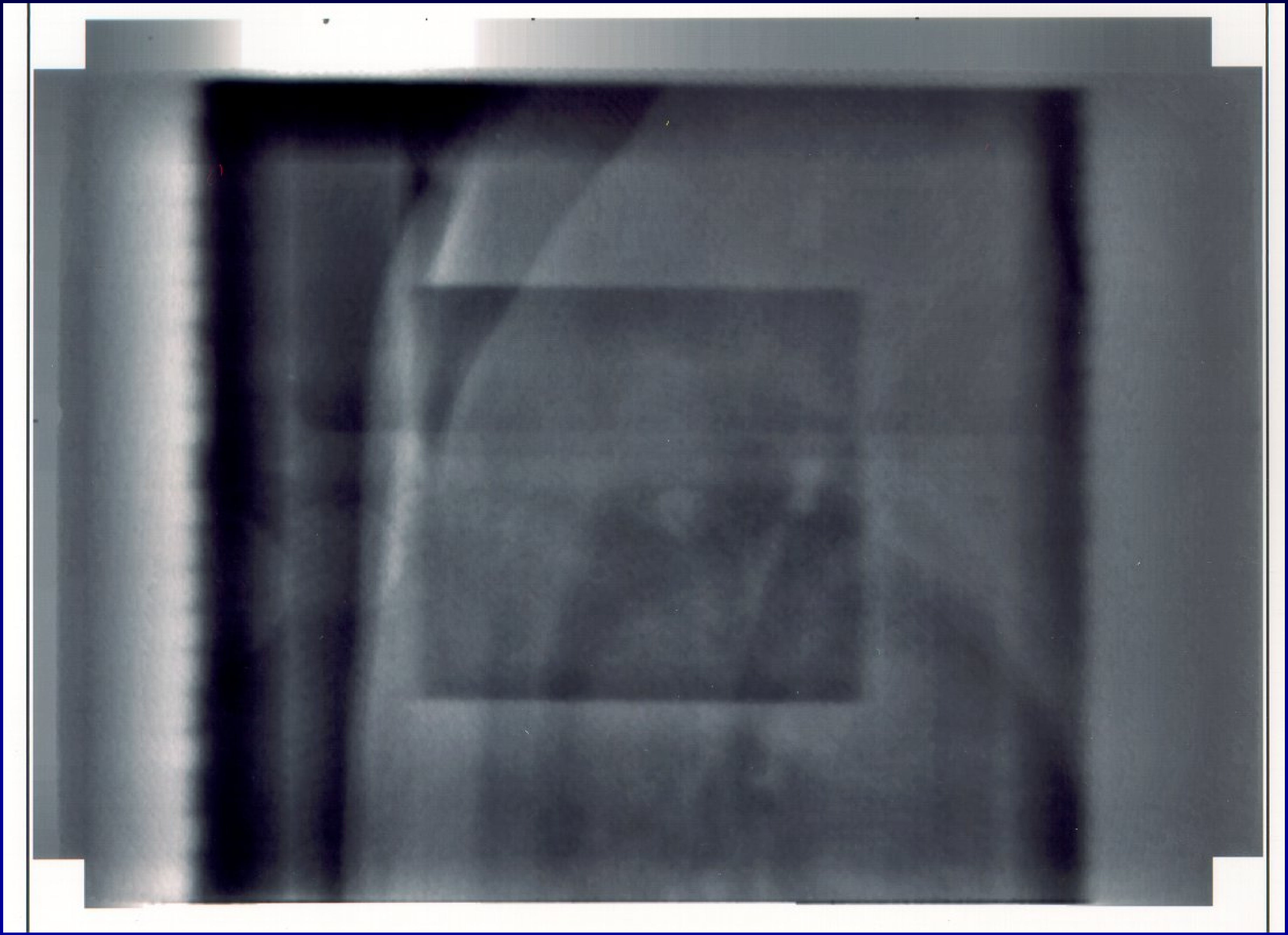
	Globale	Random	Sistematico
Laterale	3.1	2.0	2.5
Longitudinale	3.2	2.8	2.0

Samson, IJROBP, 1999


DRR Beam(# 6) ANT CEN
SBF lime green
cuore orange
polmoni green
PTV yellow
ctv red
midollo magenta




DRR Beam(# 7) LAT DX CEN
SBF lime green
cuore orange
polmoni green
PTV yellow
ctv red
midollo magenta



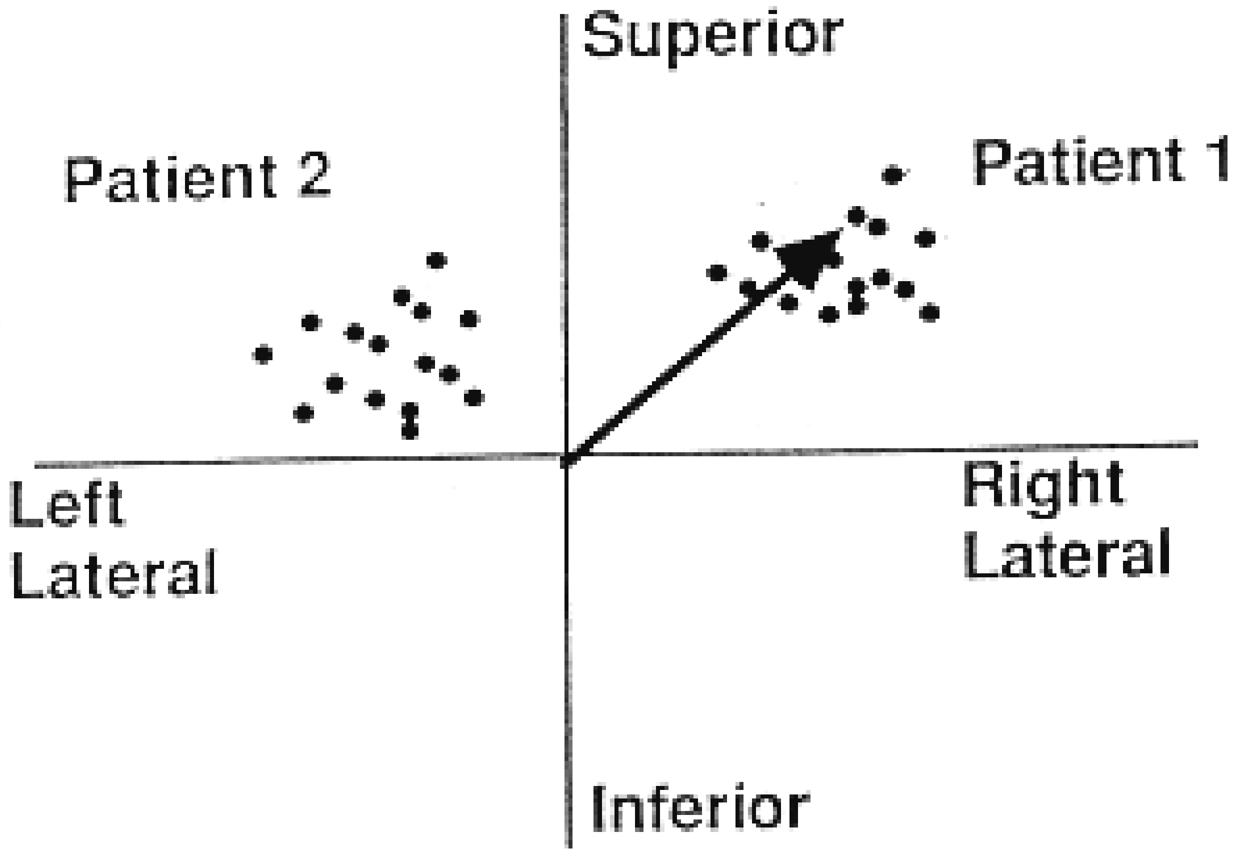


Figure 1. Random and systematic errors for two pa-

Risultati

I° Gruppo

T - bar

	c-c	lat	p-a
Errore sistematico (mm)	1.5 ± 3.5	0.3 ± 2.4	-1.1 ± 3.8
Errore random (mm)	2.1	2.1	2.3
Errore complessivo (mm)	3.7	2.8	3.7

II° Gruppo

cuscino a vuoto d'aria

	c-c	lat	p-a
Errore sistematico (mm)	0.7 ± 3.8	0.0 ± 4.8	1.3 ± 5.9
Errore random (mm)	3.7	4.1	3.1
Errore complessivo (mm)	5.3	6.0	6.3

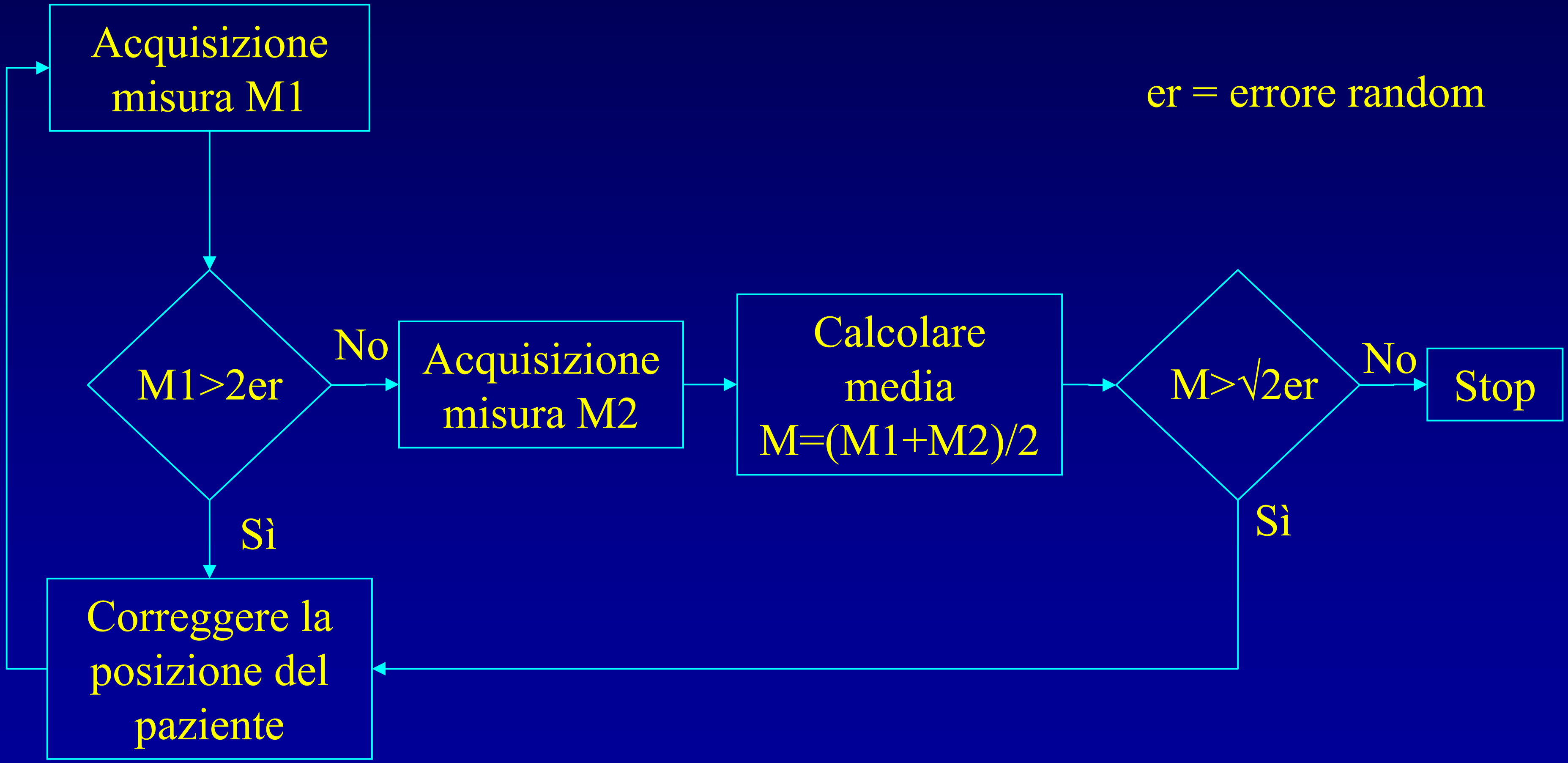
Conclusioni

- ✓ Non è stato rilevato un errore sistematico significativo nella tecnica di trattamento
- ✓ L'errore complessivo è inferiore per il sistema di immobilizzazione T bar
- ✓ Si è riscontrata una discreta probabilità di commettere un errore sistematico non trascurabile per il singolo paziente

Proposta

Introdurre un protocollo di intervento

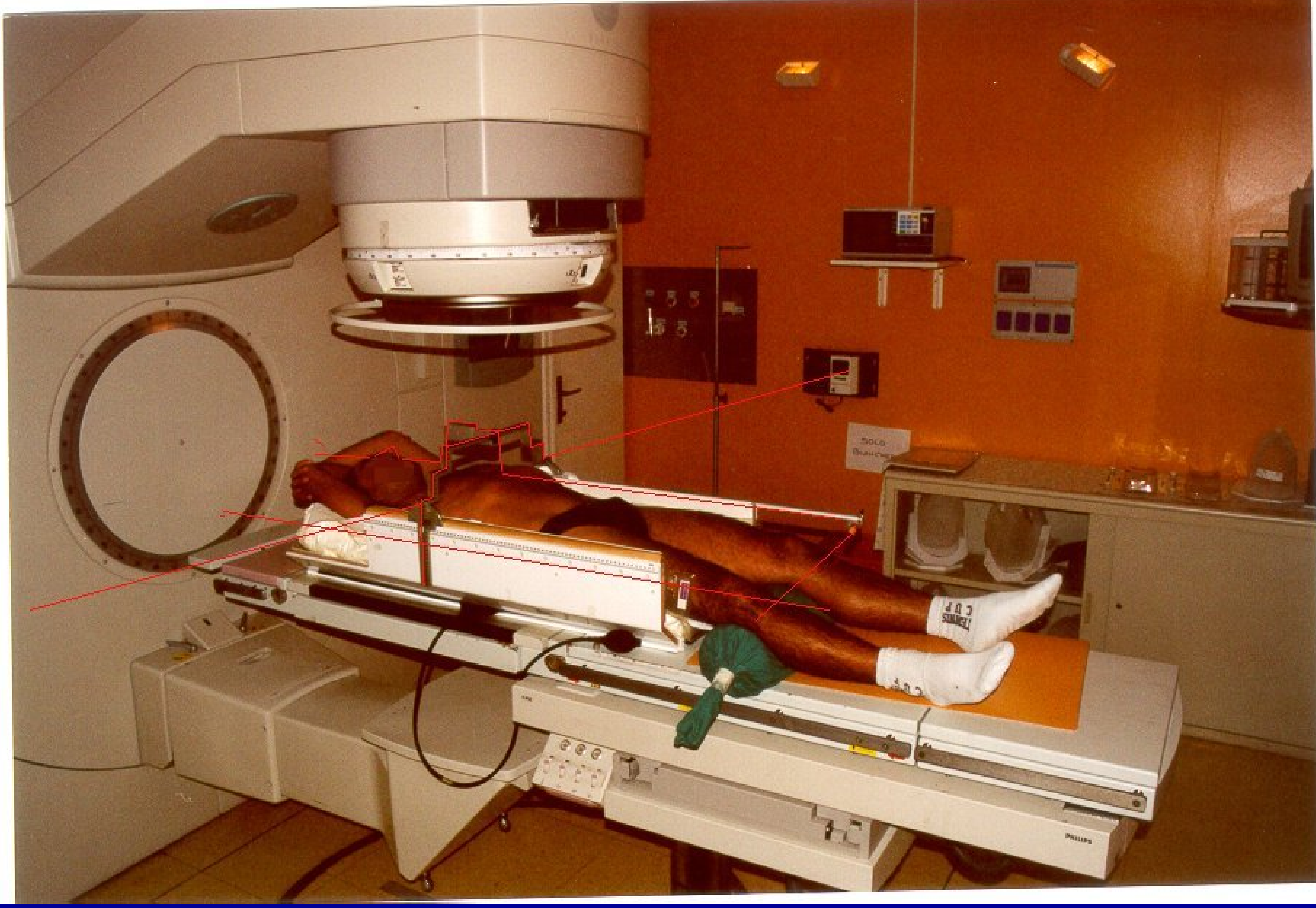
Diagramma di flusso del protocollo di intervento

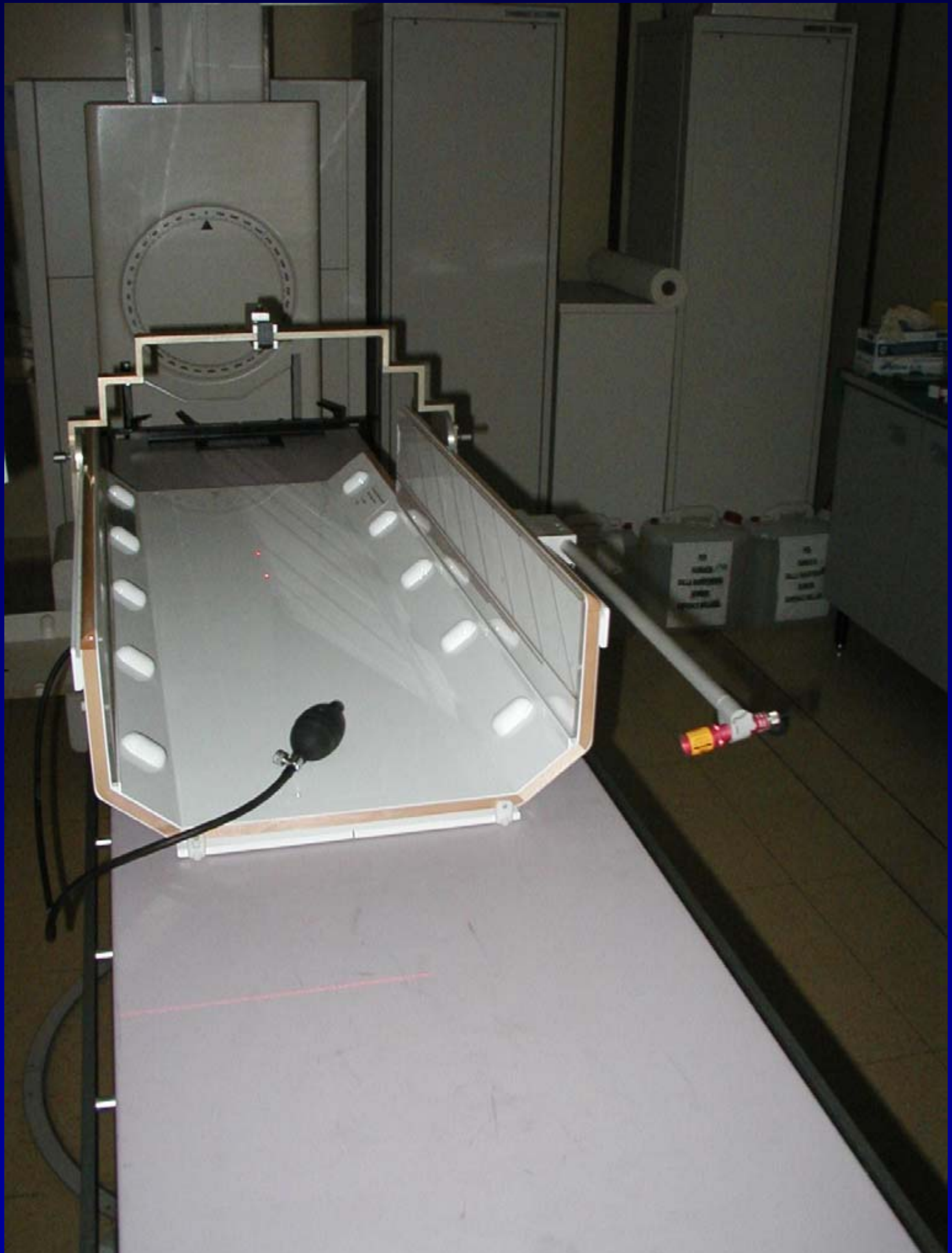


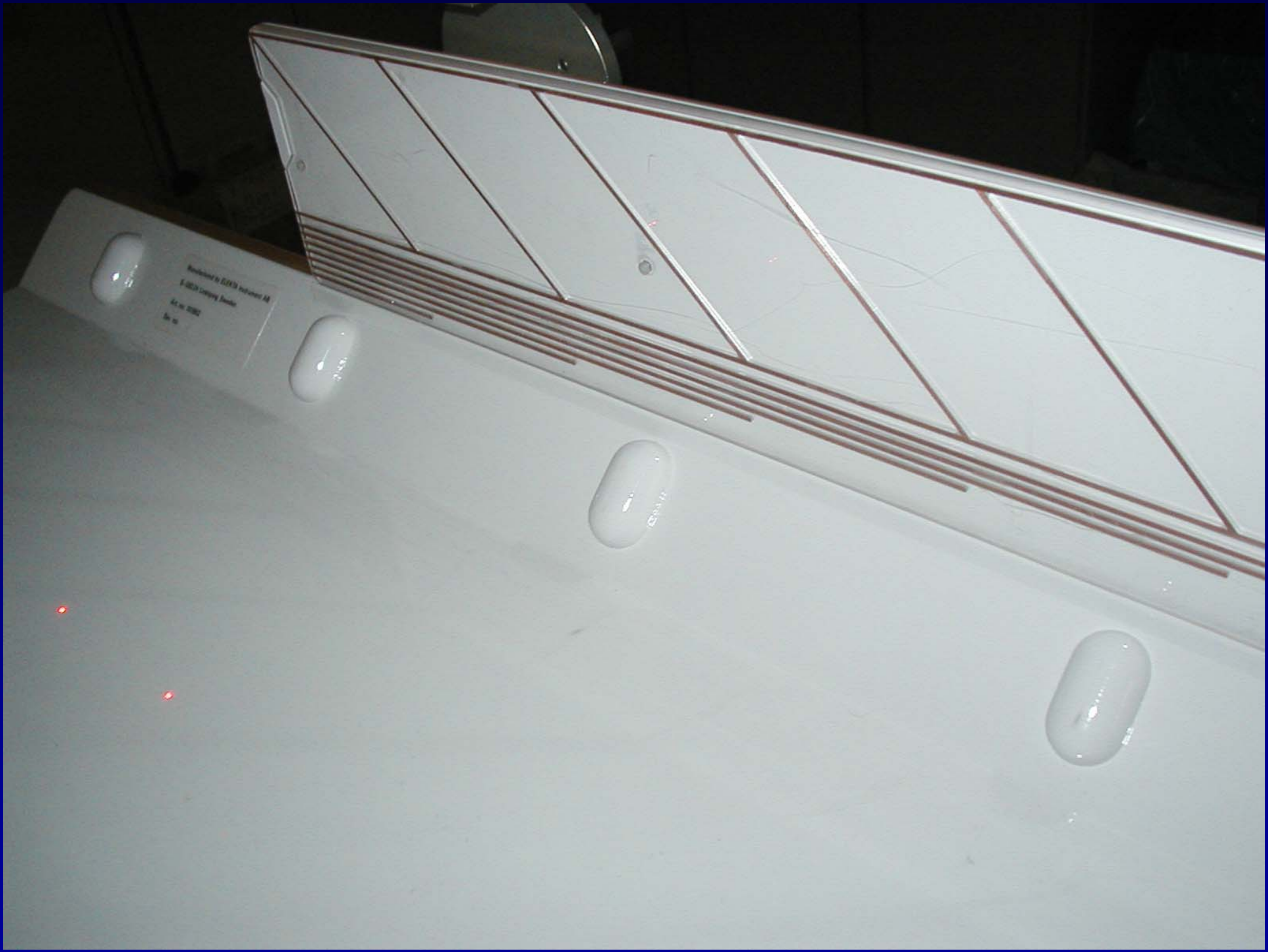
er = errore random

Numero medio di misure previste per paziente: 3.2

Numero medio di correzioni previste per paziente: 0.9

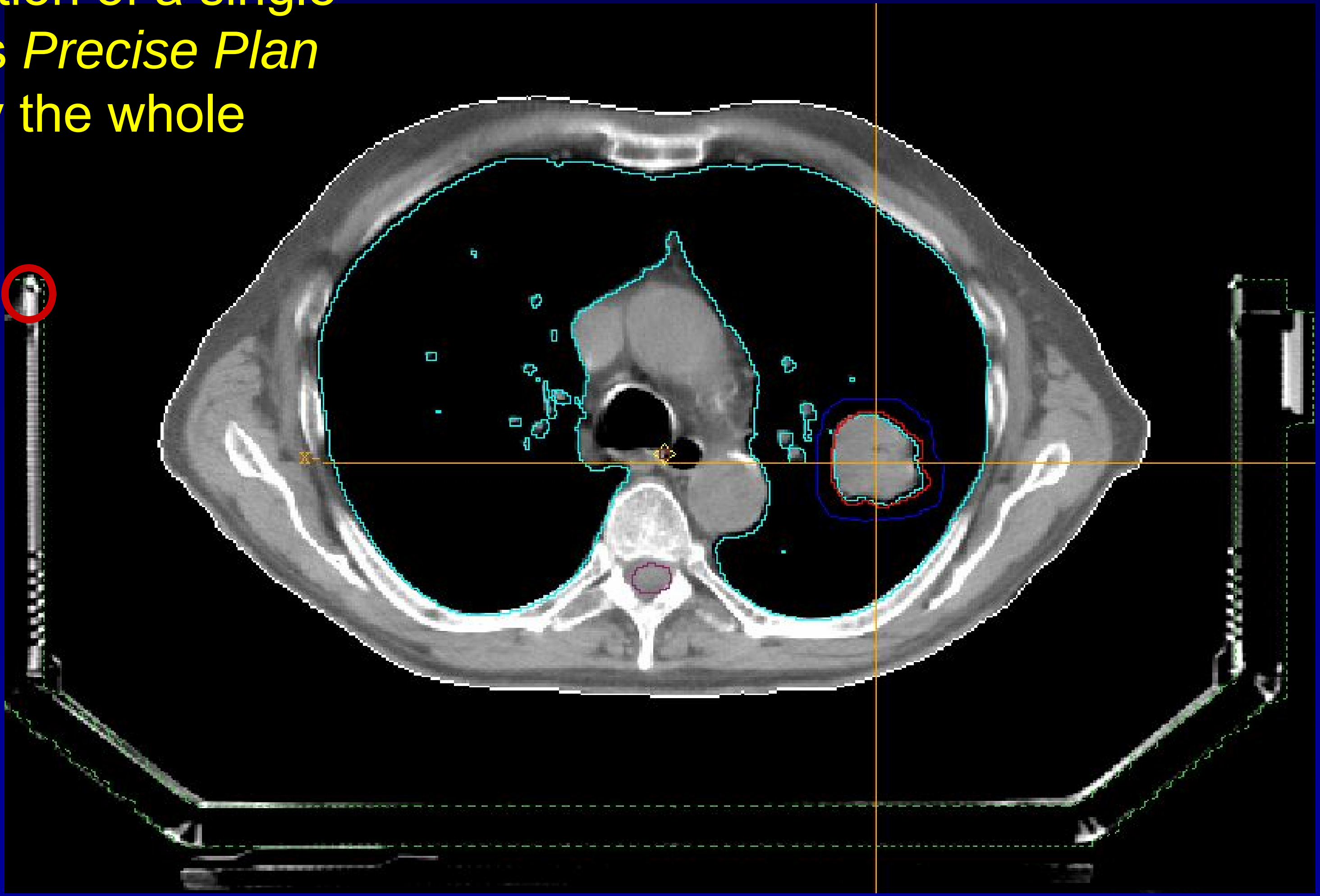






AUTOMATED IDENTIFICATION OF THE FRAME

The identification of a single marker allows *Precise Plan 3 D* to identify the whole frame



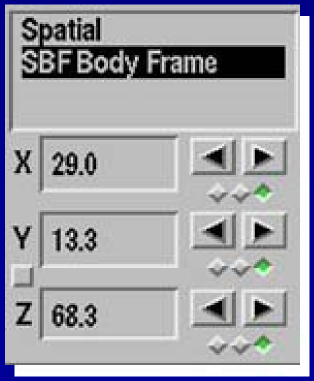


Table 2. Cumulative distributions of daily setup errors

Direction	Rate of verifications (%) <2 mm	<3 mm	<5 mm	≤8 mm
Left-right	66	85	90	100
Anterior-posterior	80	94	100	100
Cranio-caudal	59	74	93	100
3-D distance	28	58	73	98

from: Negoro, Y., IJROBP. 2001

RADIATION THERAPY IN LUNG TUMORS

CTV - PTV

- I sistemi di immobilizzazione più comunemente impiegati consentono tutti una sufficiente riproducibilità del trattamento.
- L'errore globale medio appare compreso (1 SD) tra 4 e 5 mm; si può pertanto ritenere che sia adeguato impiegare, nell'espansione da CTV a PTV, margini compresi tra 8 e 10 mm.
- Un protocollo di correzione (on line o off line) permette di rilevare eventuali errori sistematici e di correggerli
- Sistemi di immobilizzazione più sofisticati (body frame, tracking ottico) consentono margini più ridotti (5 mm)

INTERNAL MARGIN

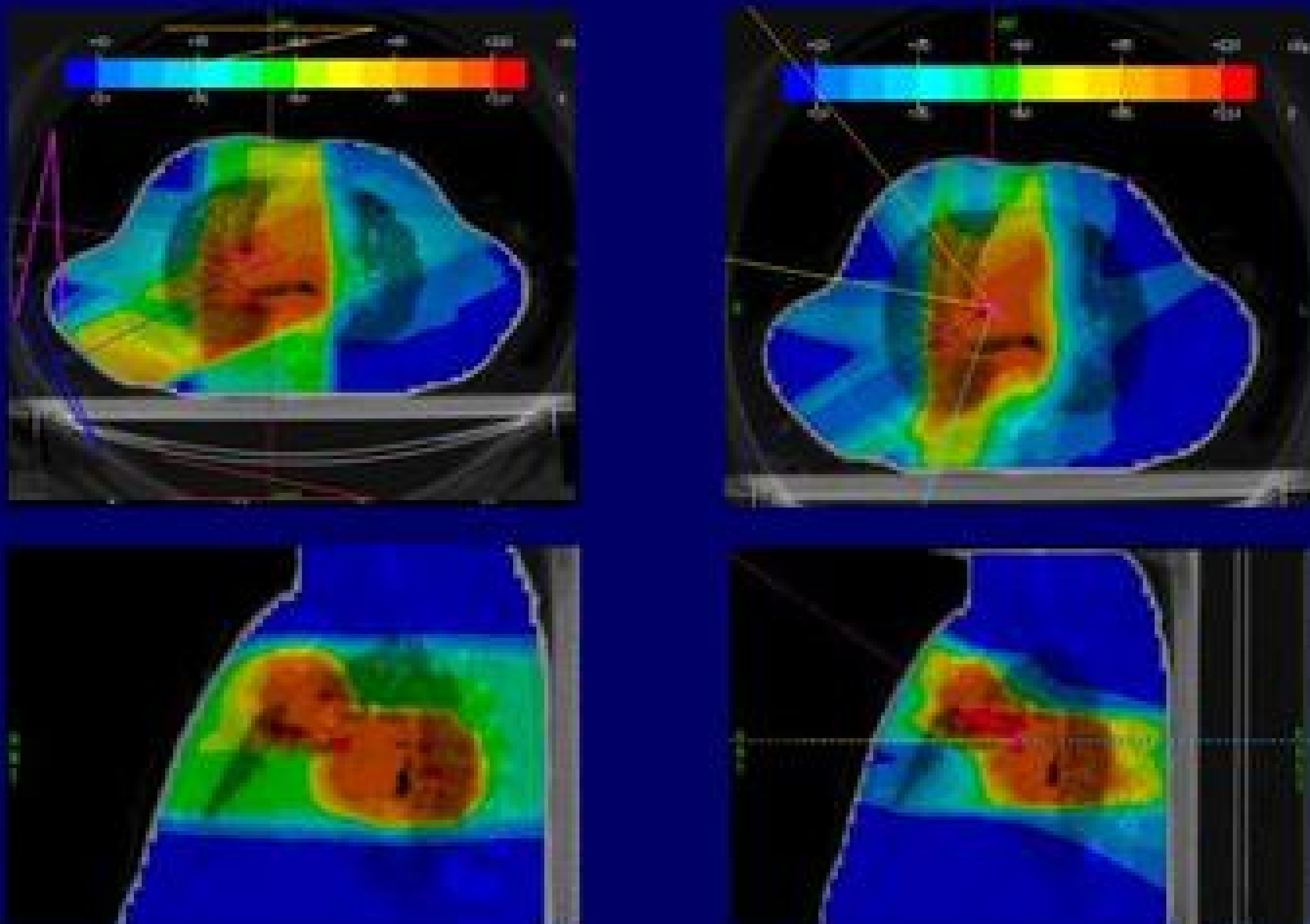
IMRT is an advanced mode of 3D-CRT

Two enhancements:

- Inverse treatment planning
- Intensity modulated treatment beams delivered with specialized tools

Comparison of 3D-CRT and IMRT Plans in Non-Small Cell Lung Cancer

3D-CRT | IMRT



Comparison of Maximum Doses for 3D-CRT and IMRT Plans in Non-Small Cell Lung Cancer

Patient	Max dose* 3D-CRT	DLS**	Max dose* IMRT	DLS
A	62 Gy	cord	80 Gy	lung, cord
B	66 Gy	lung	76 Gy	lung
C	80 Gy	lung	86 Gy	cord
D	88 Gy	lung	88 Gy	lung
E	64 Gy	cord	88 Gy	cord
F	80 Gy	cord	98 Gy	lung, cord
G	70 Gy	cord	80 Gy	cord

**Maximum dose based on Fractional Damage for lung ≤ 0.28; Spinal cord constrained to < 50 Gy; ** Dose-limiting structure*

Average increase with IMRT - 12.3 Gy; IMRT reduced NTCP for esophagus on average from 41% to 19%

MSK, 2000

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS : UNCERTAINTIES IN DEFINING CTV

- **IN LUNG TUMORS HIGH DOSES ARE NECESSARY TO IMPROVE LOCAL CONTROL.**

- **LATE DAMAGE TO LUNG IS RELATED TO DOSE DISTRIBUTION IN LUNG; IT IS THUS NECESSARY TO LIMIT THE VOLUME OF LUNG EXPOSED TO INTERMEDIATE DOSES**

- **A BETTER DEFINITION OF CTV AND A REDUCTION OF ORGAN MOTION ALLOW A REDUCTION OF THE MARGINS FROM CTV TO PTV AND REDUCE THE RISK OF LATE TOXICITY**

NEOPLASIE POLMONARI: PROBLEMI RELATIVI A IMMOBILIZZAZIONE, DEFINIZIONE DEL VOLUME BERSAGLIO E MOVIMENTO D'ORGANO: 2

Dr. G.FREZZA - U.O. Radioterapia

Dipartimento di Scienze Oncologiche

Ospedale Bellaria

AUSL Città di Bologna

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS

SET UP UNCERTAINTIES IN PLANNING PROCEDURES: CT SCAN AND SIMULATION

- GEOGRAPHICAL TUMOR MISSES ARE CAUSED BOTH BY EXTERNAL SET UP ERRORS AND BY INTERNAL MOVEMENT OF THE TARGET VOLUME.

- EXTERNAL SET UP ERRORS CONSIST OF ERRORS AT THE TREATMENT UNIT RELATIVE TO THE REFERENCE SET UP.

- EXTERNAL SET UP ERRORS CAN ALSO OCCUR BY USING SIMULATOR FILMS AS DEFINITION OF THE REFERENCE SET UP.

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS

SET UP UNCERTAINTIES IN PLANNING PROCEDURES: CT SCAN AND SIMULATION

- THE POSITION OF THE PATIENT ANATOMY IN THE REFERENCE SET UP (DURING WHICH THE TREATMENT ISOCENTER IS MARKED ON THE PATIENT AND REFERENCE IMAGES ARE OBTAINED) RELATIVE TO THE ISOCENTER SHOULD BE IN AGREEMENT WITH THE CORRESPONDING POSITION IN THE CT TREATMENT PLAN

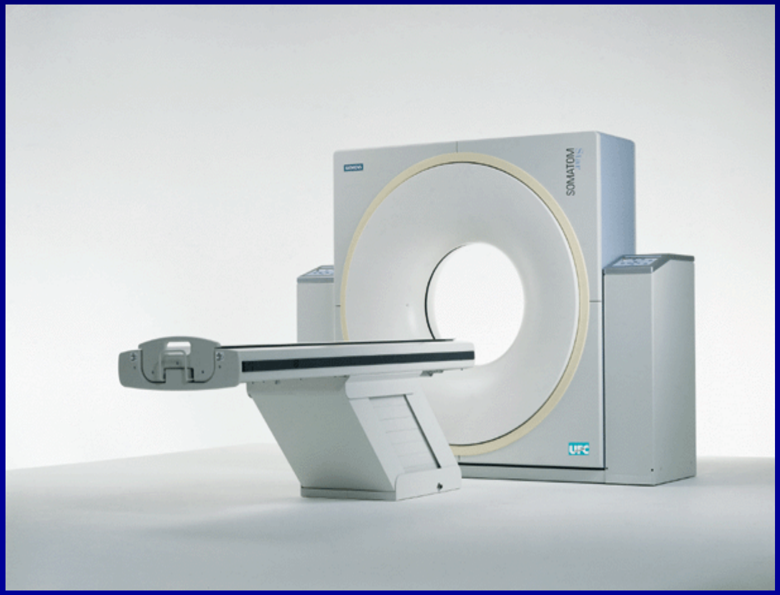
- HOWEVER IN MANY ISTITUTIONS IT IS CUSTOMARY TO MARK THE FINAL BEAM SET UP AT THE SIMULATOR AFTER THE PLANNNING HAS BEEN PERFORMED

- THE DEFINITION OF THE FINAL ISOCENTER IS BASED ON VISUAL INSPECTION OF SIMULATION IMAGES, AND THEREFORE MAY DEVIATE FROM THE INTENDED ISOCENTER

- THIS SIMULATOR SET UP ERROR RESULT IN A SYSTEMATIC ERROR IN THE PATIENT TREATMENT

IMMAGINI per la costruzione di un sistema geometrico di riferimento

I riferimenti geometrici individuati durante la prima fase TAC devono essere mantenuti durante il *percorso radioterapico*



TAC centratura

↓

Piano Trattamento

↓

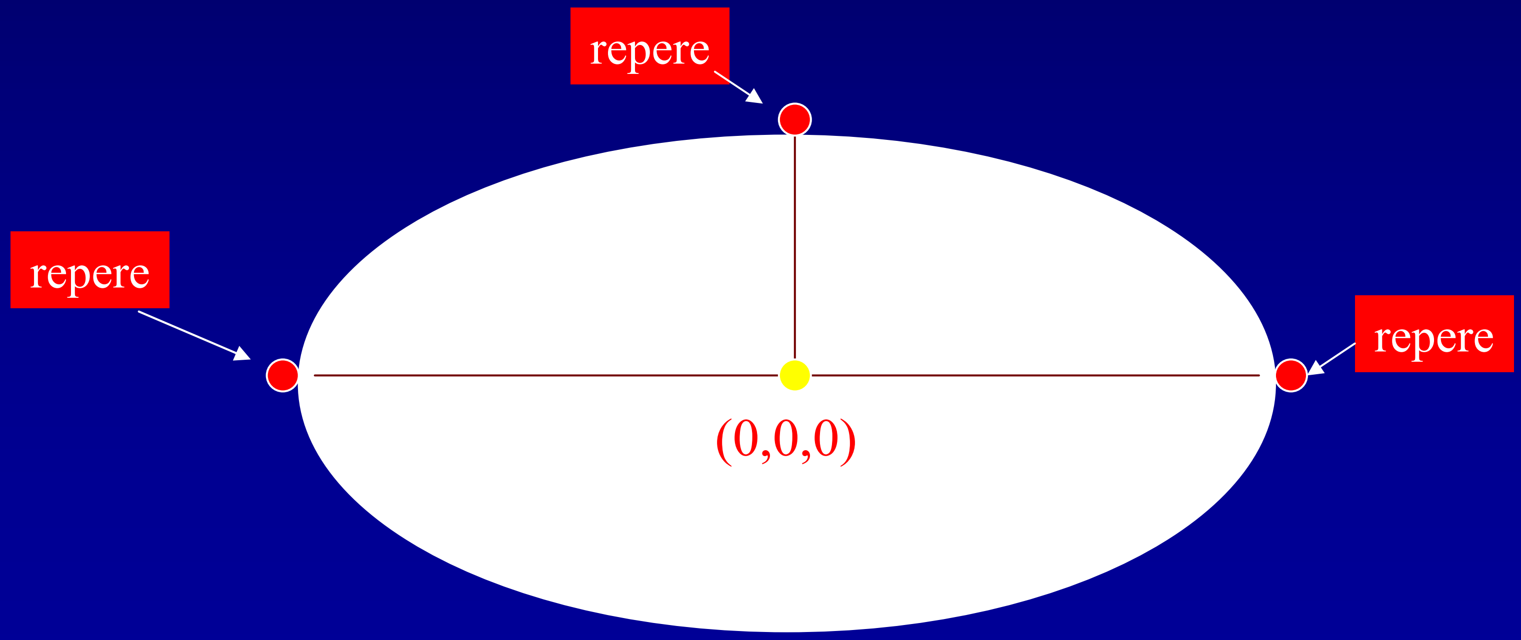
Simulazione ?

↓

Trattamento

IMMAGINI per la costruzione di un sistema geometrico di riferimento

TAC centratura



La Simulazione Tradizionale

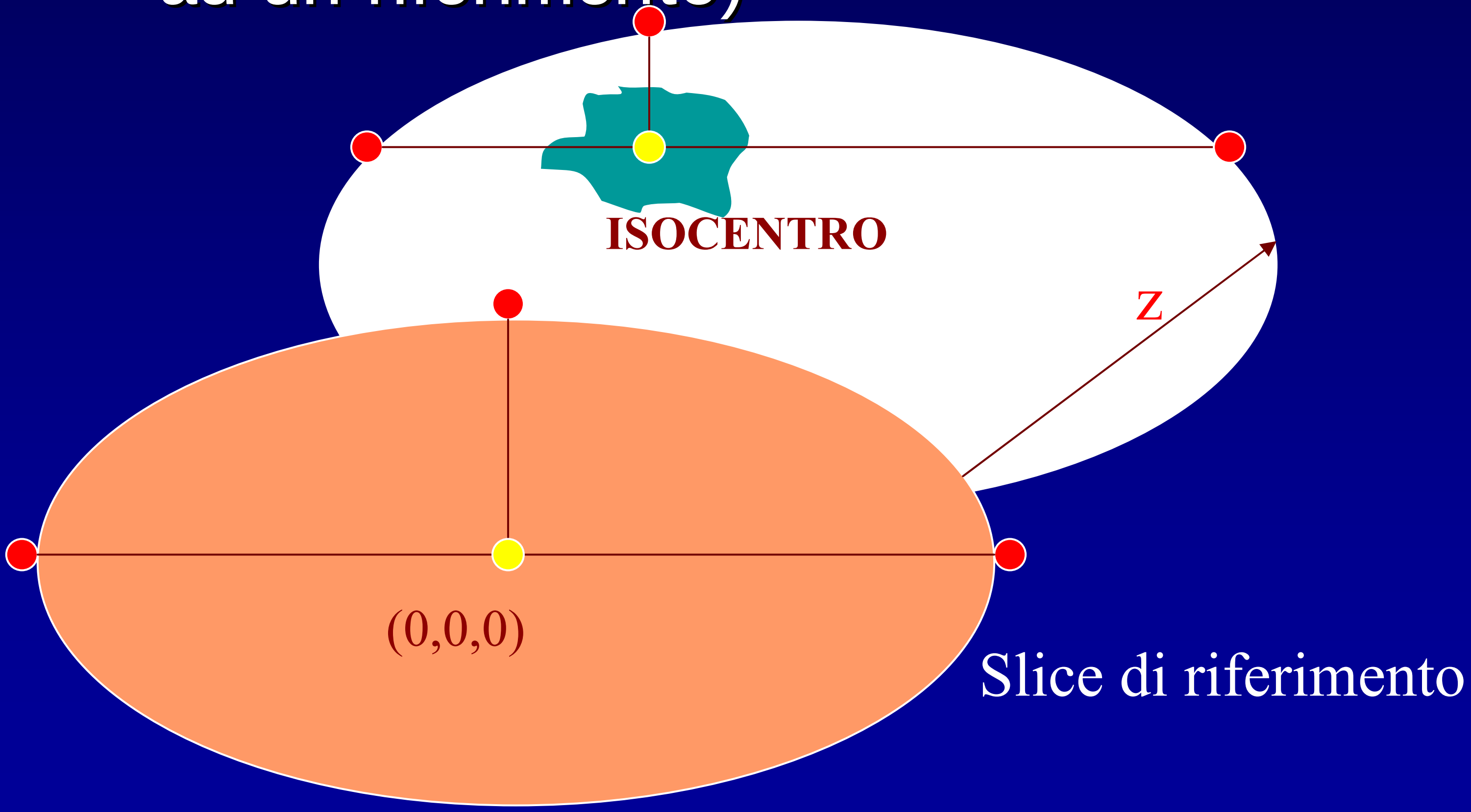
viene effettuata al fine di:

- a) traslare sul paziente i riferimenti geometrici previsti nel Piano di Trattamento

- b) verificare mediante immagini radiologiche l'accuratezza geometrica della posizione dei campi di radiazione (rispetto a quanto previsto nel Piano di Trattamento)

Simulazione Tradizionale

Viene individuato sul paziente l' **ISOCENTRO** del trattamento (traslazione x, y, z rispetto ad un riferimento)



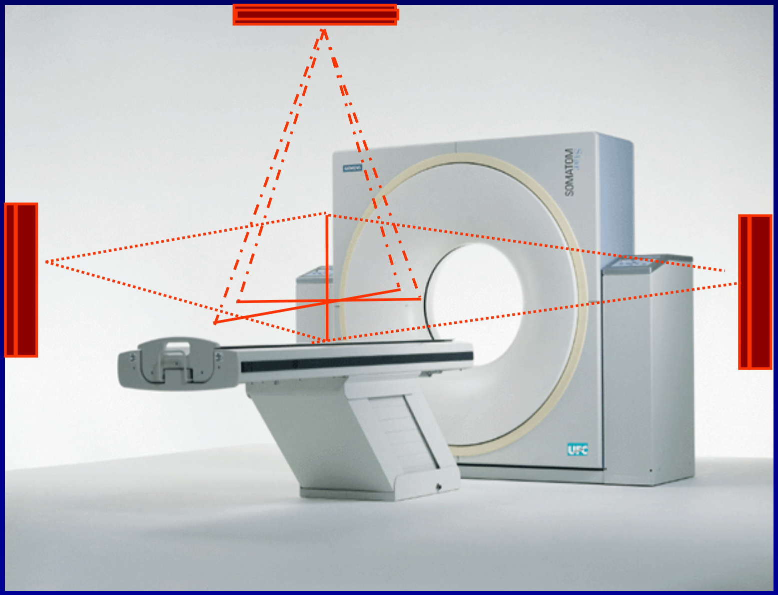
Simulazione Virtuale

La **Simulazione Virtuale** è una procedura di Radioterapia con le medesime finalità della **Simulazione Tradizionale**

Virtuale significa che la procedura non richiede l'utilizzo di una Unità di Simulazione

Simulazione Virtuale

Ricerca dell'ISOCENTRO sul paziente

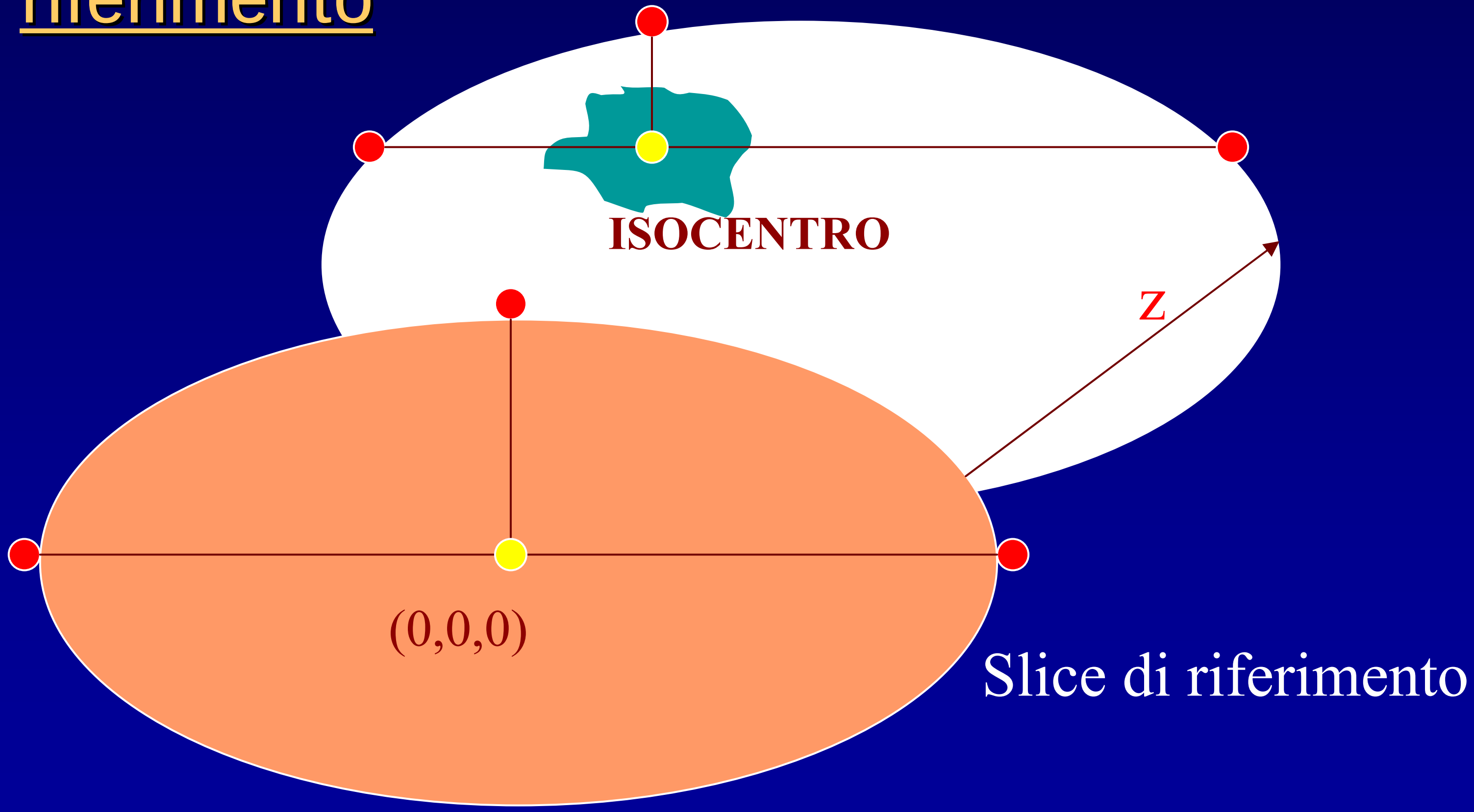


Sistema a Laser Mobili

Simulazione Virtuale

Viene individuato sul paziente l' **ISOCENTRO** del trattamento

I LASER vengono traslati nel punto x, y, z rispetto ad u riferimento



IMMAGINI per la visualizzazione della distribuzione di dose

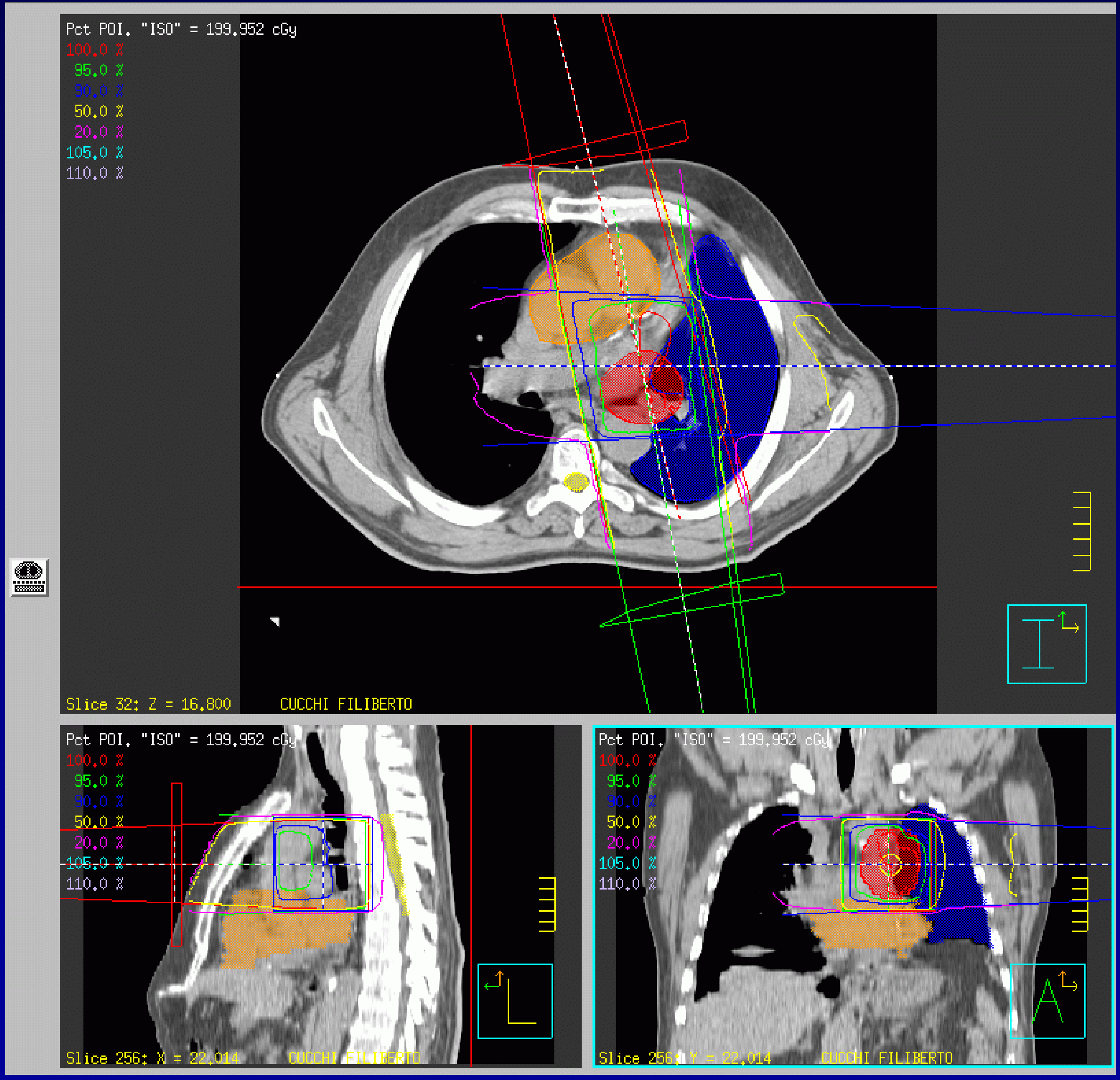
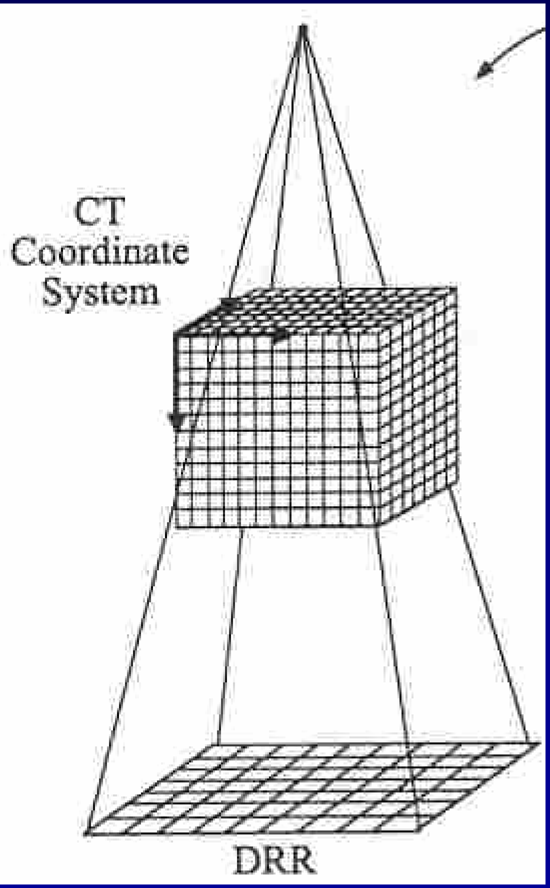


Immagine DRR

Elaborazione del CT data set algoritmo di calcolo



<u>Modello fisico di attenuazione</u> : da una sorgente viene generato un fascio di raggi X virtuale che va ad incidere sul "modello paziente" (CT data set). Il fascio così attenuato genera un'immagine radiologica (la DRR).

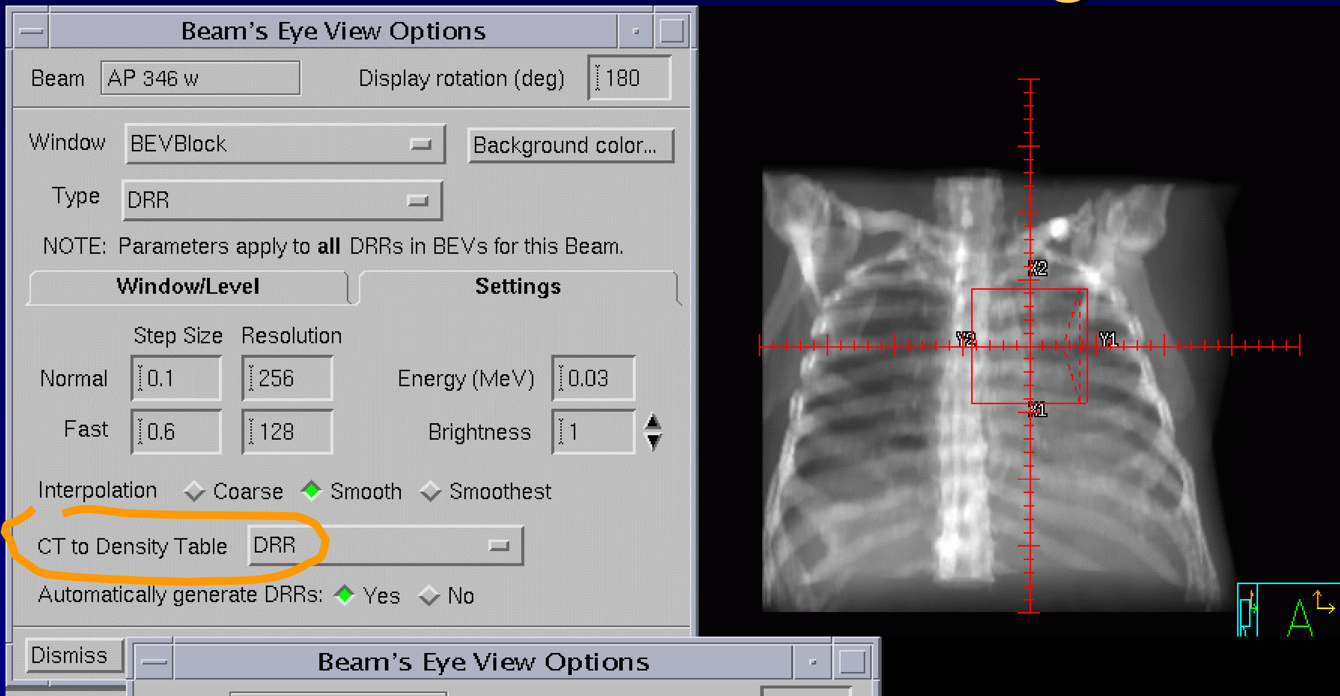
In ogni VOXEL avviene una attenuazione del fascio dipendente dal μ (si tiene conto solo della componente primaria del fascio)

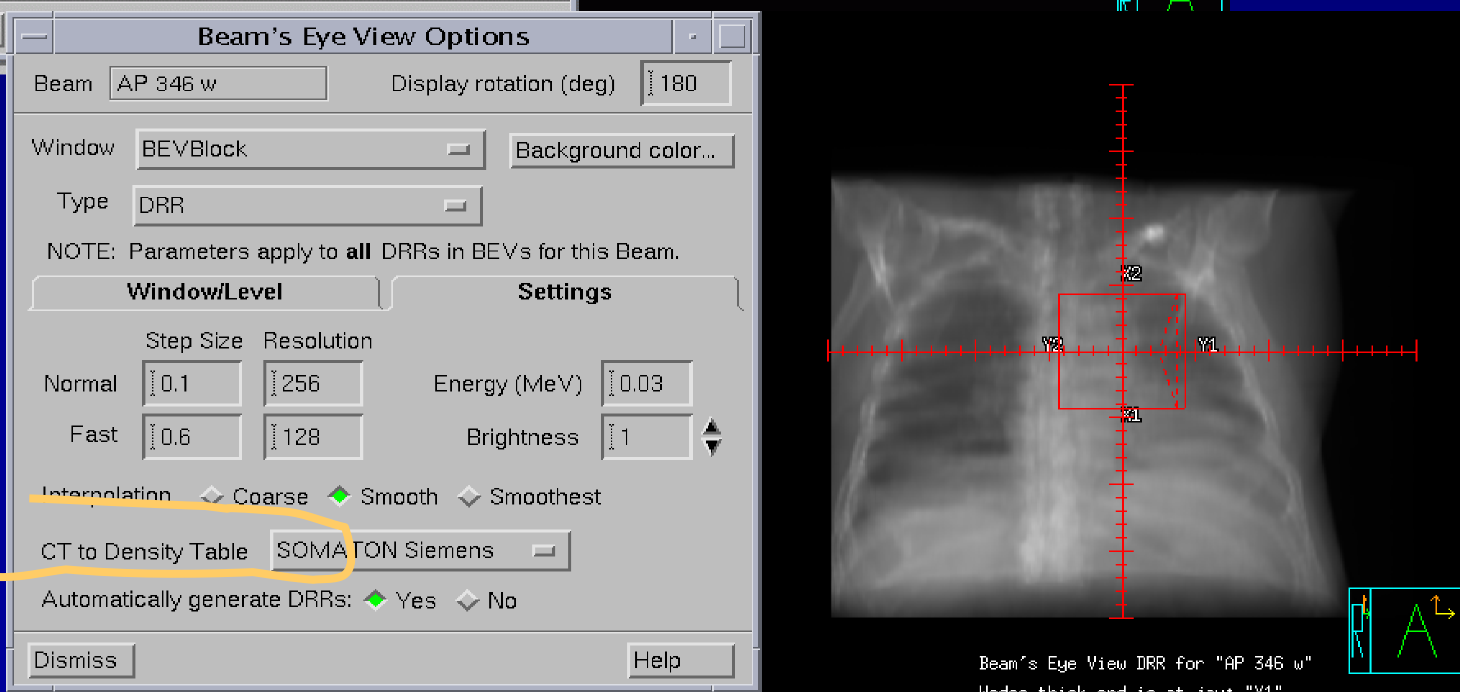
IMMAGINI per la verifica geometrica del trattamento

Immagine DRR
Digitally Reconstructed Radiographs

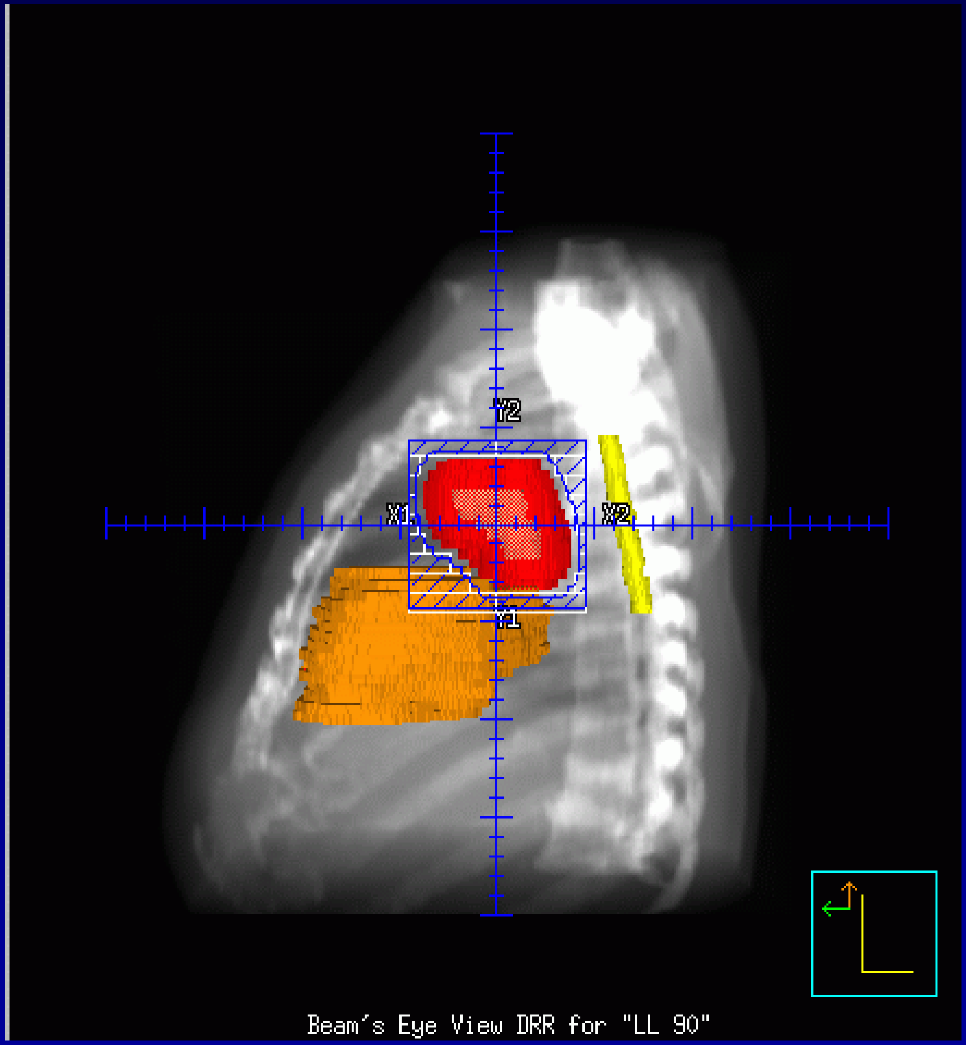
È un'immagine planare (2D) ottenuta da una elaborazione (proiezione su un piano) di un insieme volumetrico "**CT data set**" (3D) ricavato mediante l'indagine CT di centratura con il paziente in posizione di cura

confronto Immagini DRR



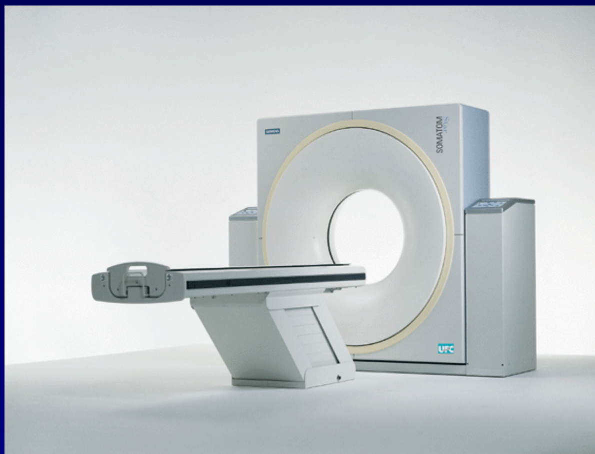


altre caratteristiche dell'Immagine DRR



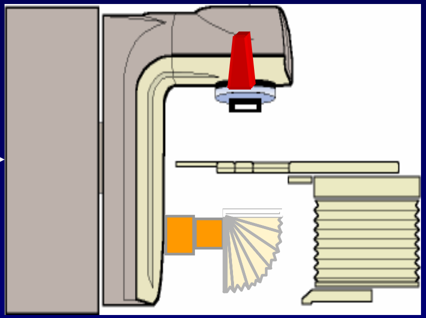
Confronto delle IMMAGINI

3D-Conformal



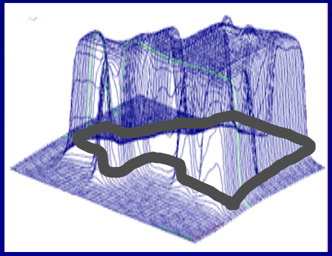
CT Unit

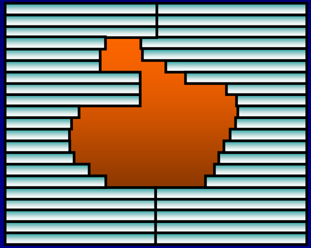
Plan Definition Virtual Simulation

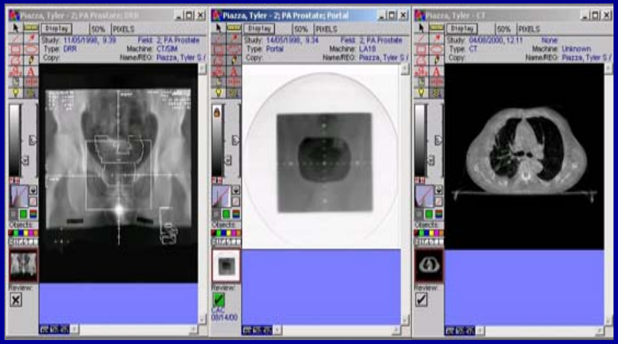


Verify & Treatment

- **CTV & PTV Plan Definition**
- **Organ at Risk Definition**
- **Geometrical Set-Up Definition**
- **Portal Images Verification**







Portal Images Verification

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS

SET UP UNCERTAINTIES IN PLANNING PROCEDURES: CT SCAN AND SIMULATION

Set up differences between DRR and simulator films: 39 pts

	x (mm)	y (mm)	z (mm)
Mean	0,4	0,6	0,3
SD	4,0	2,8	2,5
Max	9,0	8,0	8,0

De Boer, IJROBP 2003

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS

SET UP UNCERTAINTIES IN PLANNING PROCEDURES: CT SCAN AND SIMULATION

CTV-PTV margins M in mm for set up varations only: 39 pts

	x (mm)	y (mm)	z (mm)
Reference: sim film	7	12	11
Reference: CT scan	5	8	9
Reference: CT scan with correction protocol	4	4	5

Margins: $M = 2\,\Sigma + 0{,}7\,\sigma$

Σ = standard deviation of systematic error; σ = average of random error

De Boer, IJROBP 2003

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS

SET UP UNCERTAINTIES IN PLANNING PROCEDURES: CT SCAN AND SIMULATION

- Setup errors at the simulator become systematic errors if the simulation defines the reference set up
- The omission of a separate simulation step can reduce systematic errors
- Systematic errors can be furtherly reduced with the application of an off line correction protocol
- Such a protocol should be based on DRR
- The definitive isocenter can be marked directly at the CT scan, omitting the simulation step and its associated errors

HYPOFRACTIONATED STEREOTACTIC RADIOTHERAPY:

ANALYSIS OF DOSIMETRIC IMPLICATIONS OF SET UP ERRORS

CONVENTIONAL RADIATION THERAPY IN EARLY STAGE LUNG TUMORS

LOCAL FAILURE RATE AFTER IF RT (CT based plans): T1-T2 N0 pts

Author	Total dose/days	BED late	BED acute	LFR%
Noordijk	60 Gy/47	120,0	63,4	70
Slotman	48 Gy/16	112,0	76,4	6
Cheung	52.5 Gy/26	98,4	67,8	41
Morita	64.7 Gy/44	107,8	65,3	44

BED late = nd x (1 + d / alfa/beta)

BED acute = nd x (1 + d / alfa/beta) – ln2 x (T- Tk) / (alfa x Tpot)

STEREOTACTIC RADIATION THERAPY IN EARLY STAGE LUNG TUMORS

LOCAL FAILURE RATE AFTER HYPOFRACTIONATED IF RT (CT based plans): T1-T2 N0 pts

Author	Pts	Dose/ N.Fx	Local control
Uematsu	50	50 Gy/5 *	96%
Nagata	33	48 Gy/4 ^	92%
Arimoto	24	60 Gy/8 ^	94%
Wulf	17	45 Gy/3 *	94%
Hof	5	26 Gy/1^	100 %

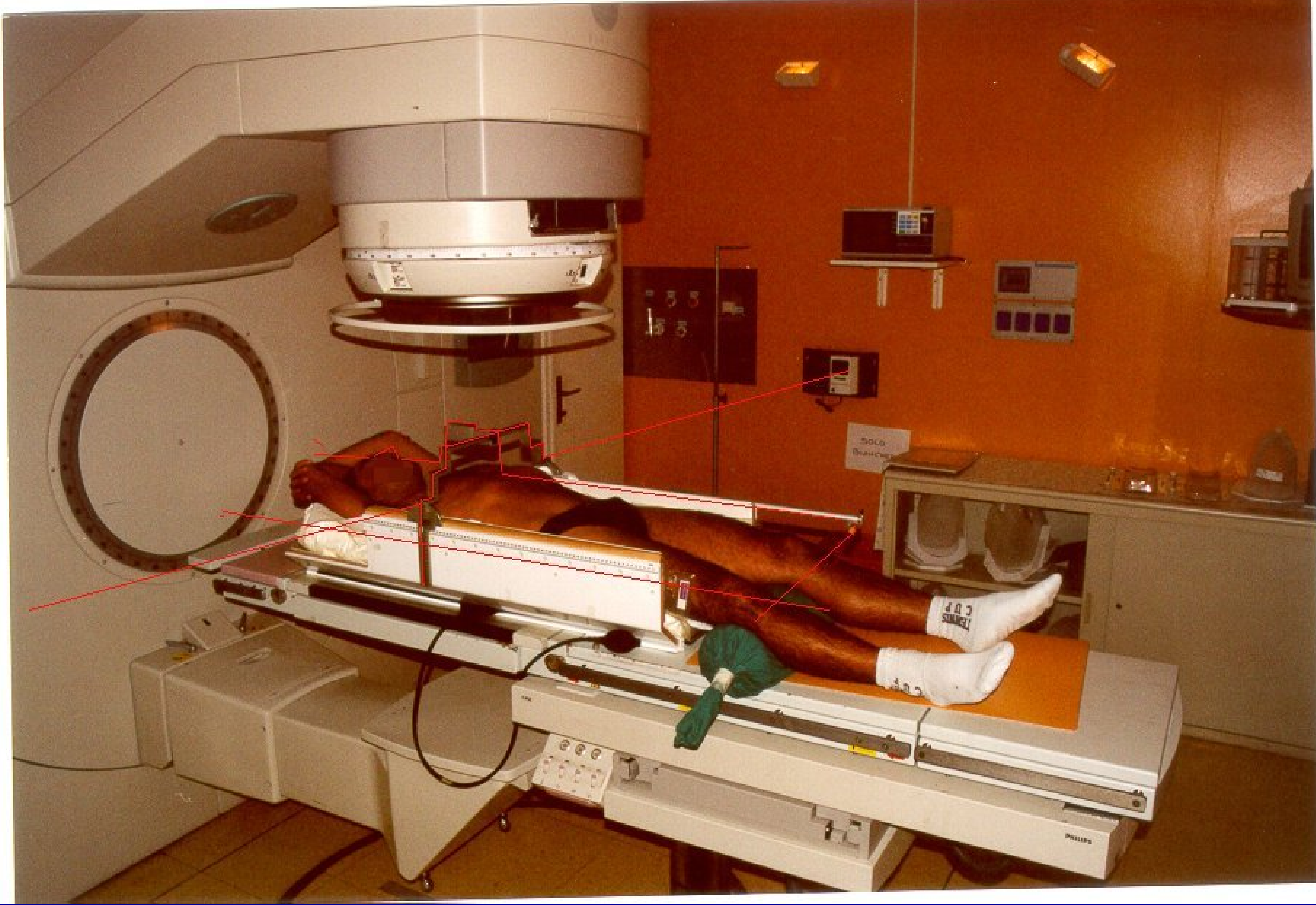
* Prescribed to reference isodose

^ Prescribed to isocenter

CLINICAL EXPERIENCE AT OSPEDALE BELLARIA

STEREOTACTIC RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS AT OSPEDALE BELLARIA

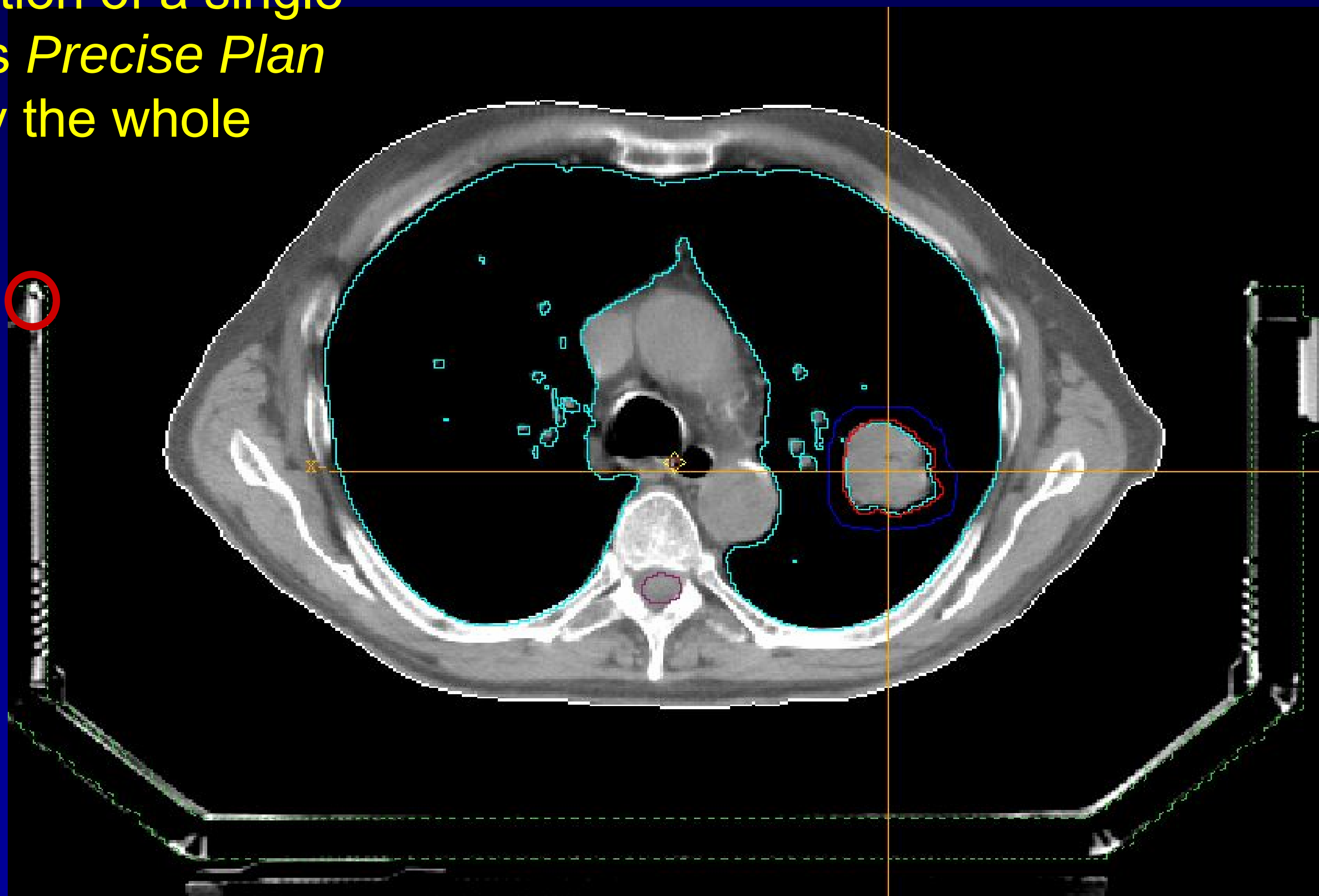
- April 2001- January 2004
- 56 pts, 21 females and 35 males
- Age: 44-81 years
- 61 lesions; 25 primary NSCLC T1 N0: 17 pts
  T2 N0: 8 pts
  36 metastases (mainly from colon ca)

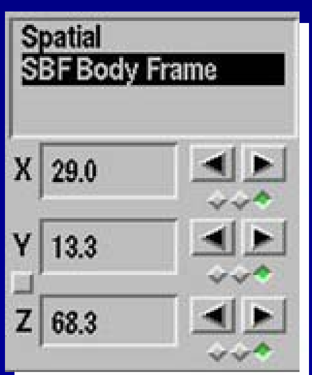


Controlled compression of of abdominal wall was emploied only when fluoroscopy showed a motion of the target of > +/- 7 mm

AUTOMATED IDENTIFICATION OF THE FRAME

The identification of a single marker allows *Precise Plan 3 D* to identify the whole frame



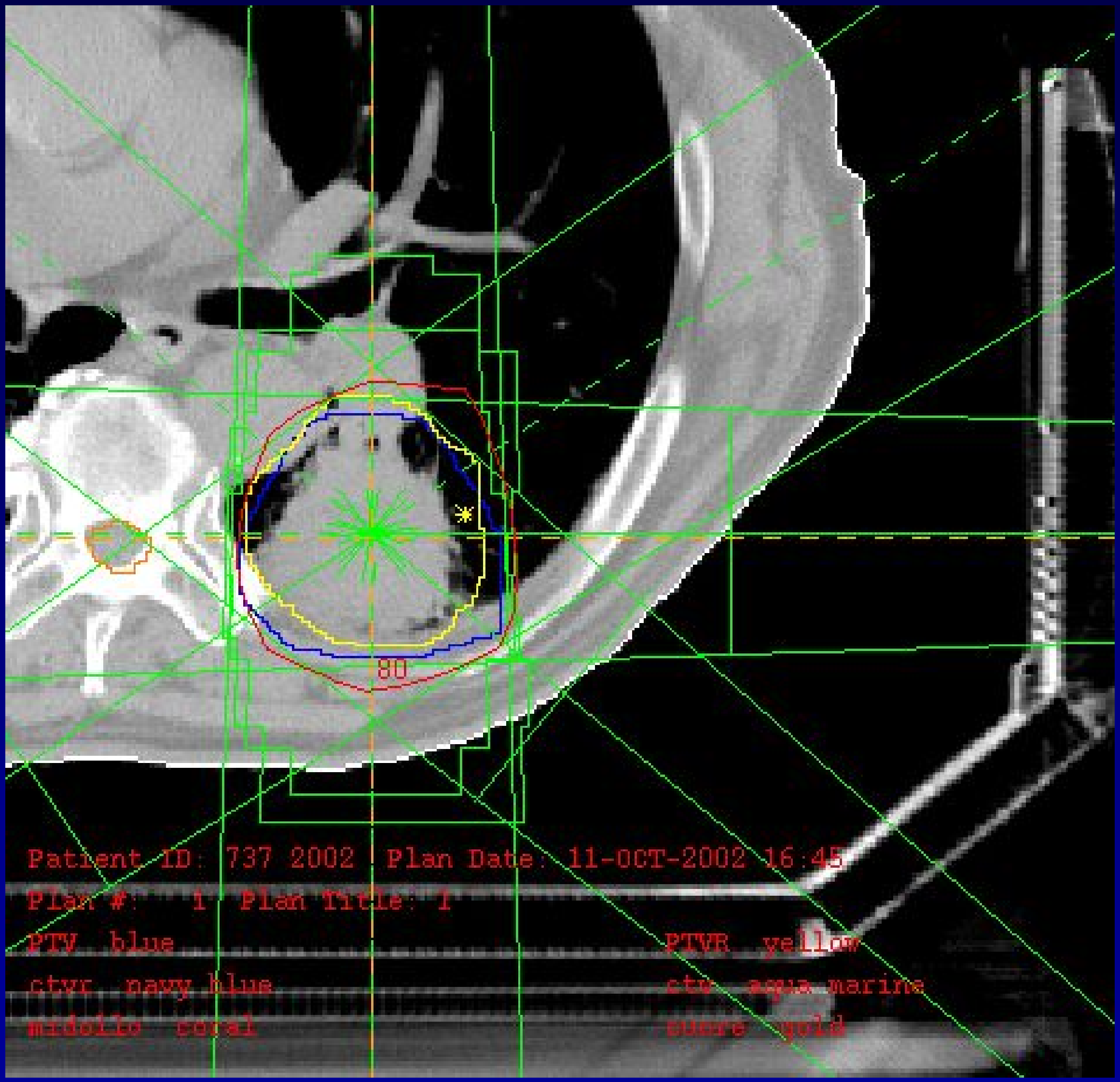


STEREOTACTIC RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS AT OSPEDALE BELLARIA

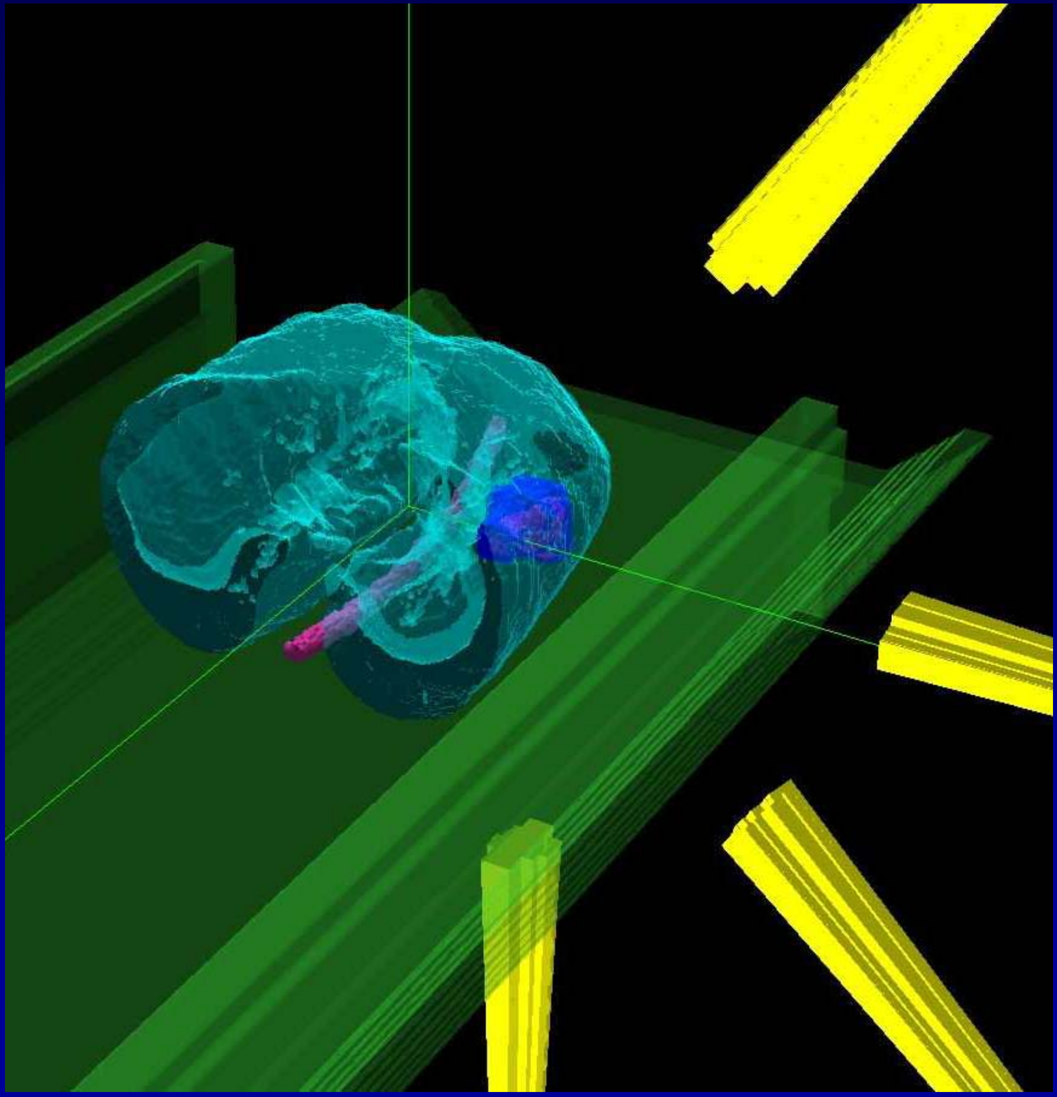
- GTV and OAR were delineated on CT scan acquired for treatment planning (3 mm spaced sections)

- CTV was obtained with a 5 mm isotropic expansion of GTV

- PTV was obtained adding to CTV a 5 mm margin on transversal plane and a 10 mm margin in cranio-caudal direction


80
Patient ID: 737 2002 Plan Date: 11-OCT-2002 16:45
Plan #: 1 Plan Title: 1
PTV blue
PTVR yellow
ctvr navy blue
ctv aqua marine
midollo coral
cuore gold

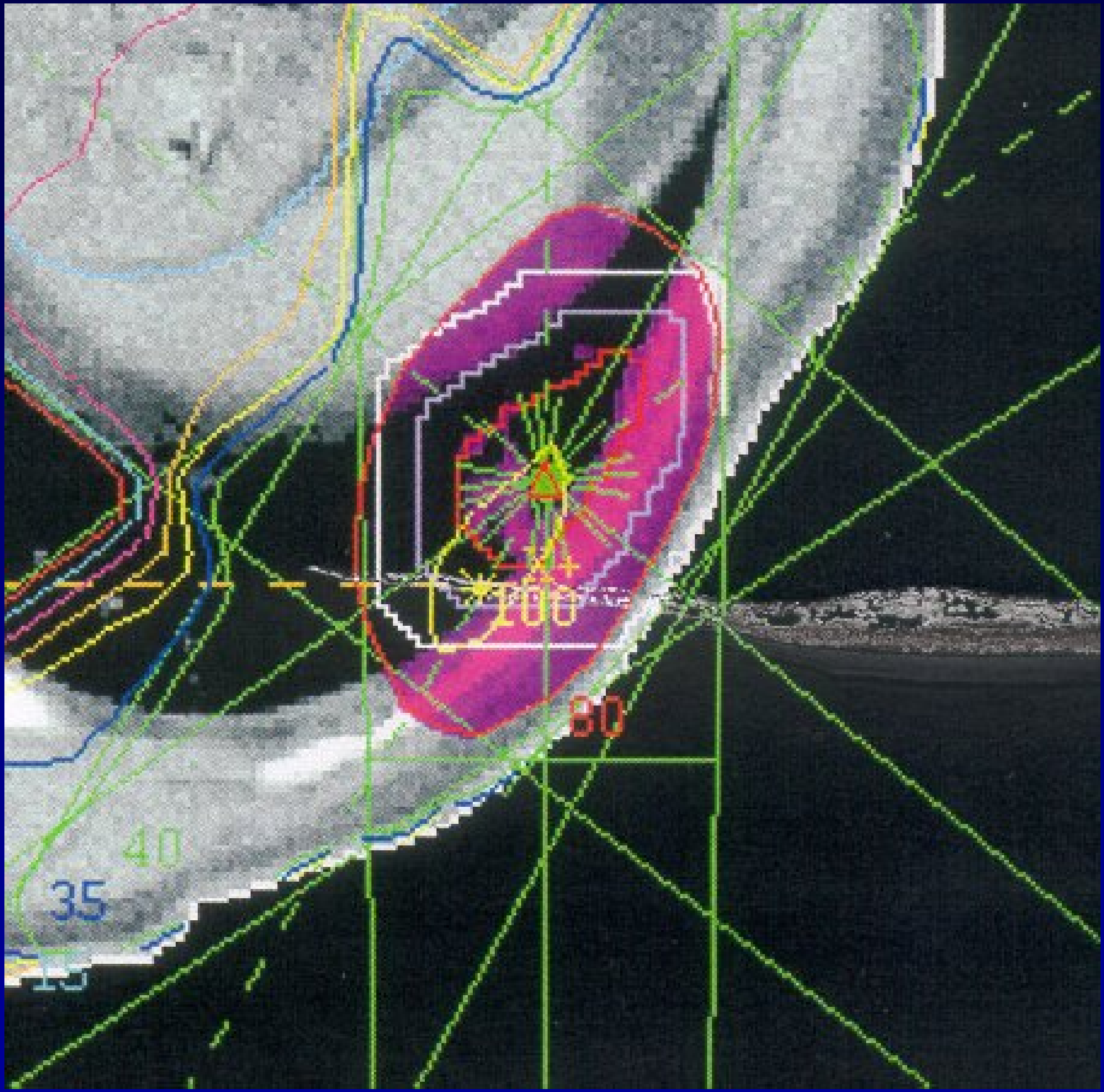
TREATMENT PLANNING



Treatment technique

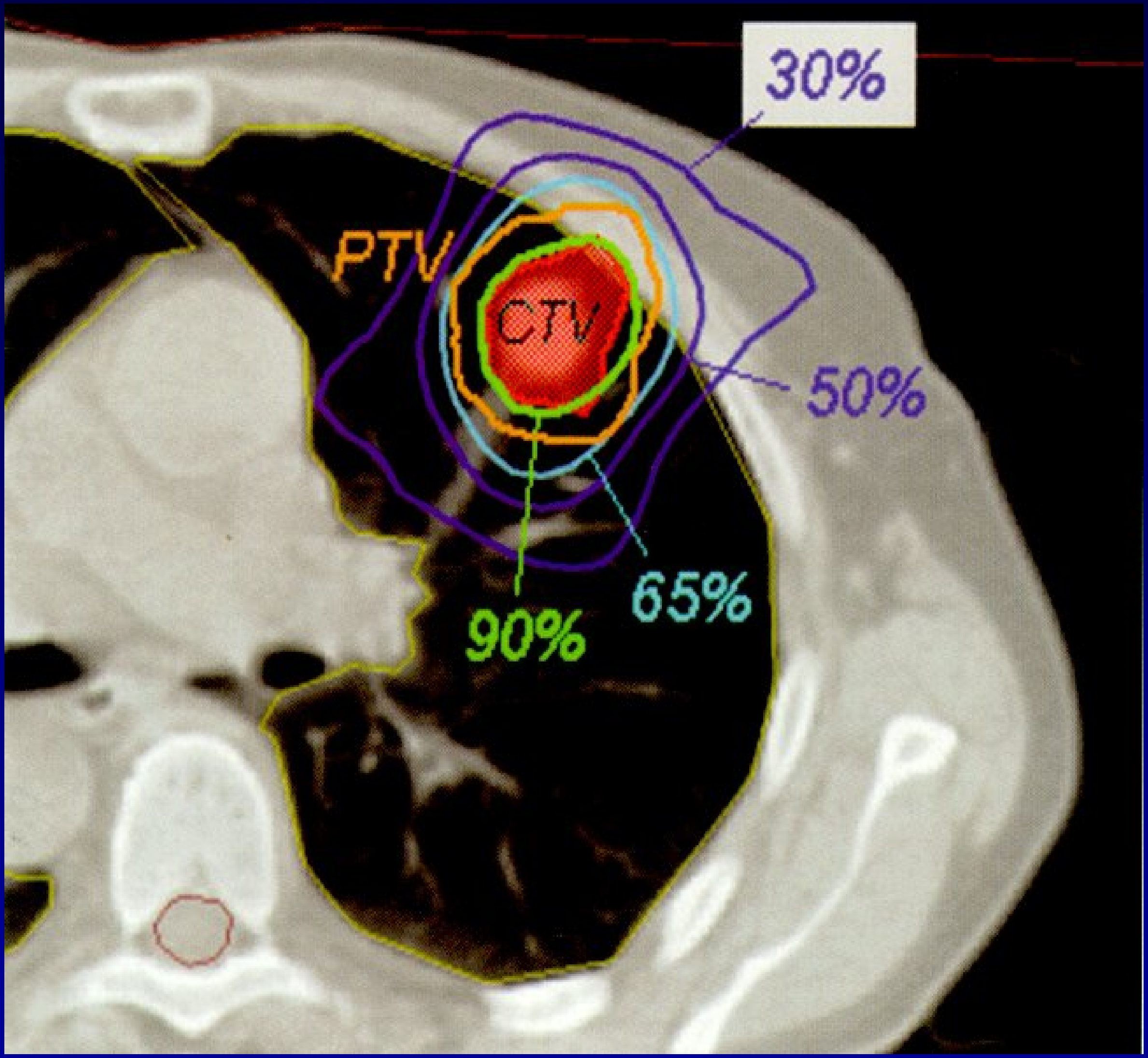
- 4-7 static fields, 6-10 MV
- Conformation with MLC
- Not coplanar fields distributed over a wide solid angle
- No opposed fields

Graphical representation of the Stereotactic Body Frame.

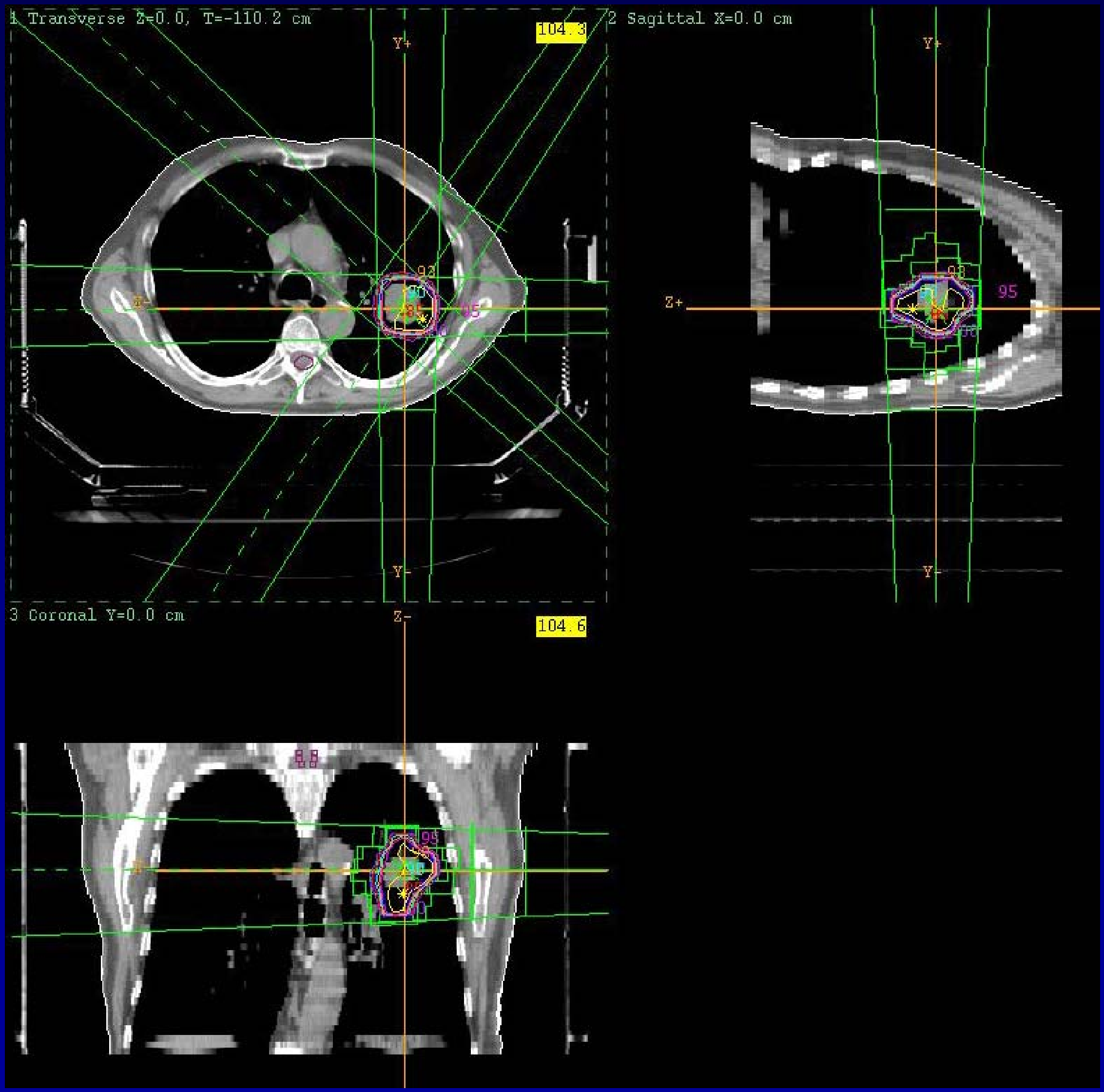


THE USE OF MULTIPLE CONFORMED NOT COPLANAR BEAMS CAN INCREASE THE CONFORMITY NUMBER AND CAN DETERMINE A RAPID DECREASE NOT ONLY OF TOTAL DOSE, BUT ALSO OF DOSE PER FRACTION.
THIS EFFECT REDUCES THE RISK OF TOXICITY IN LATE REACTING TISSUES

CN(conformity number)= PTV ref / PTV x PTV ref / V ref = 0,82

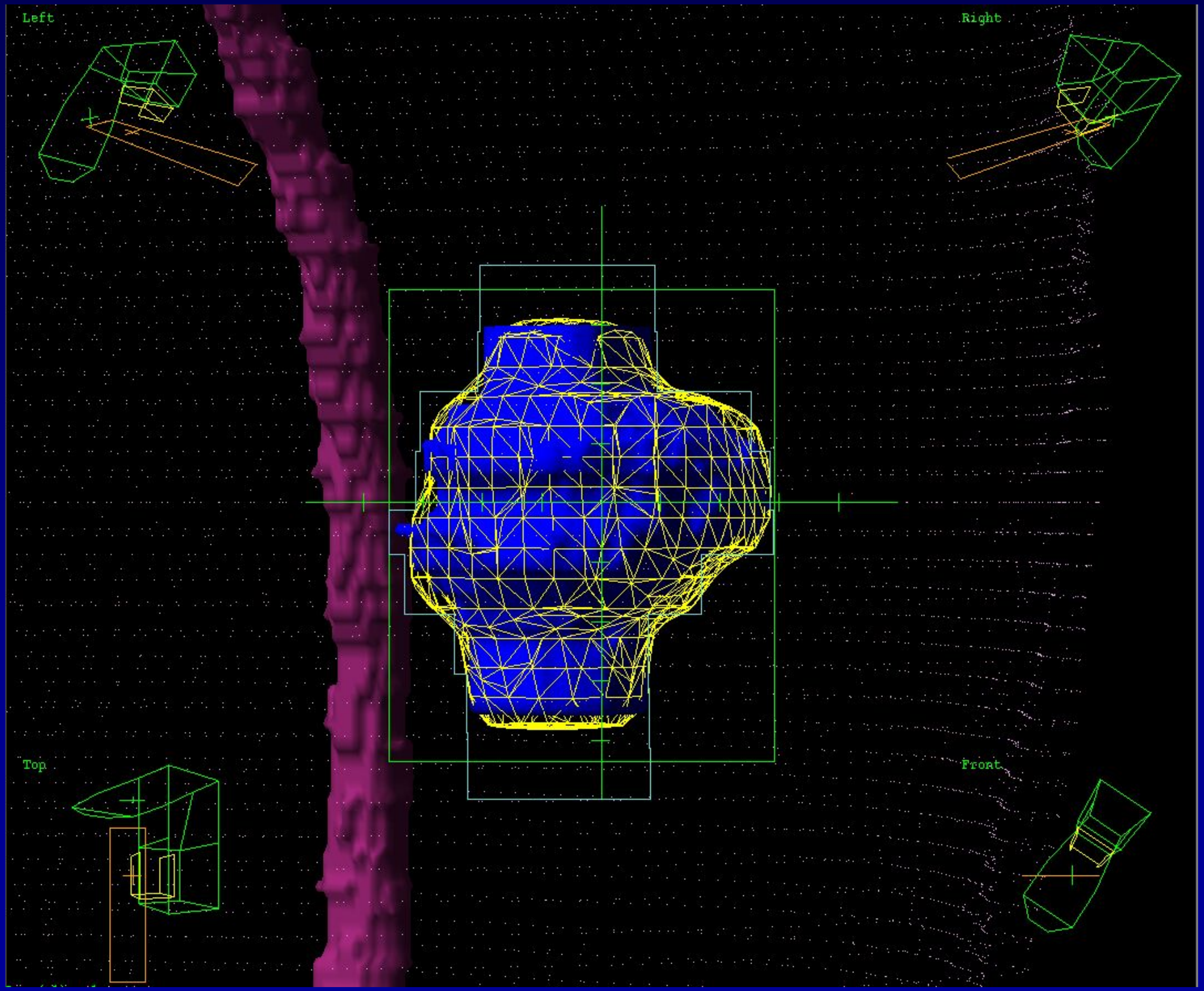

30%
PTV
CTV
50%
65%
90%

DOSE PRESCRIPTION



- Isocenter = point of dose normalization
- Minimal dose to PTV: 80%
- Dose inhomogeneity to PTV: 20-30% (110-80% of dose to isocenter)

FRACTIONATION



Primary tumors:

5 fractions

10 Gy / fraction to isocenter

8 Gy / fraction to 80% isodose

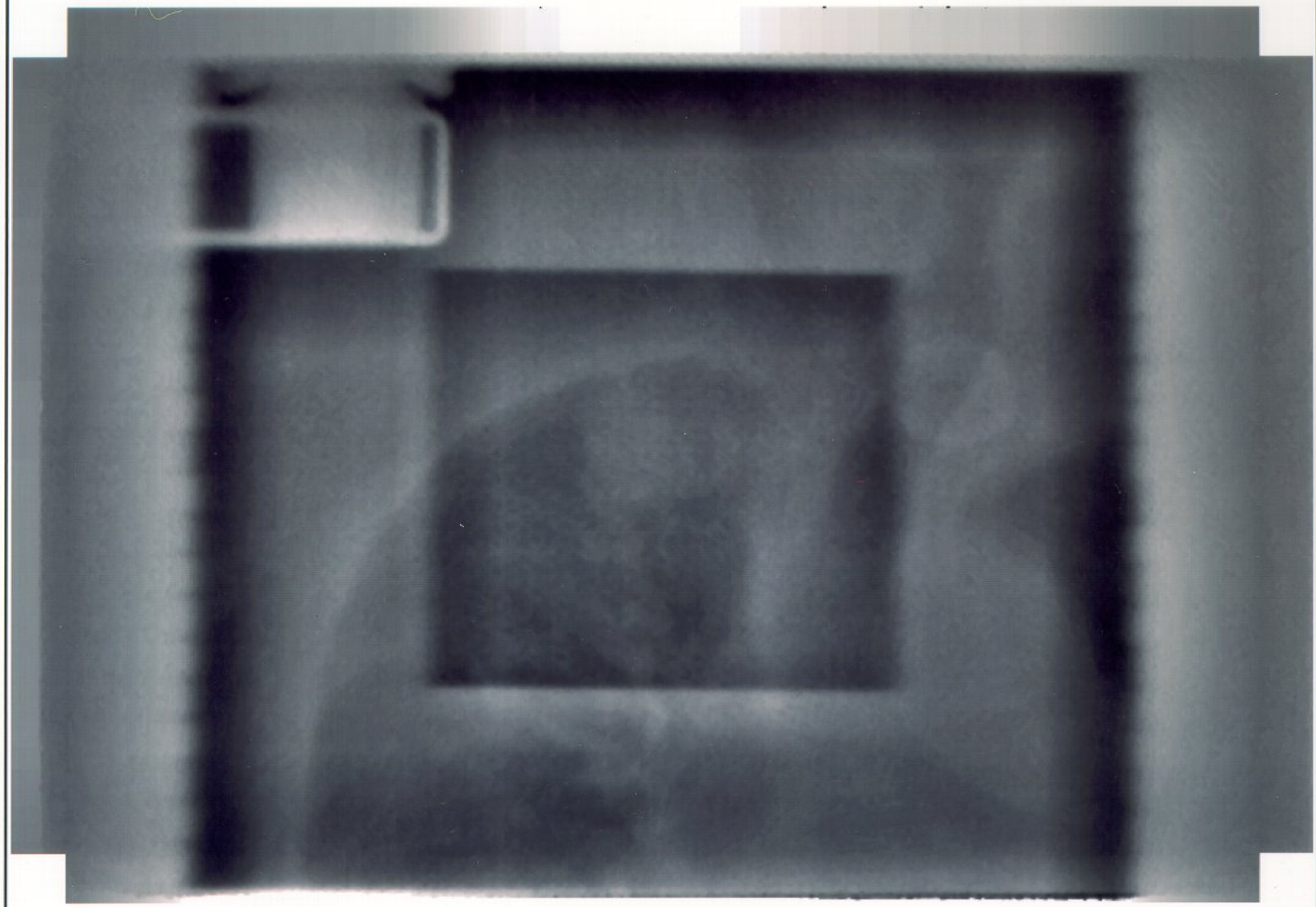
Metastases

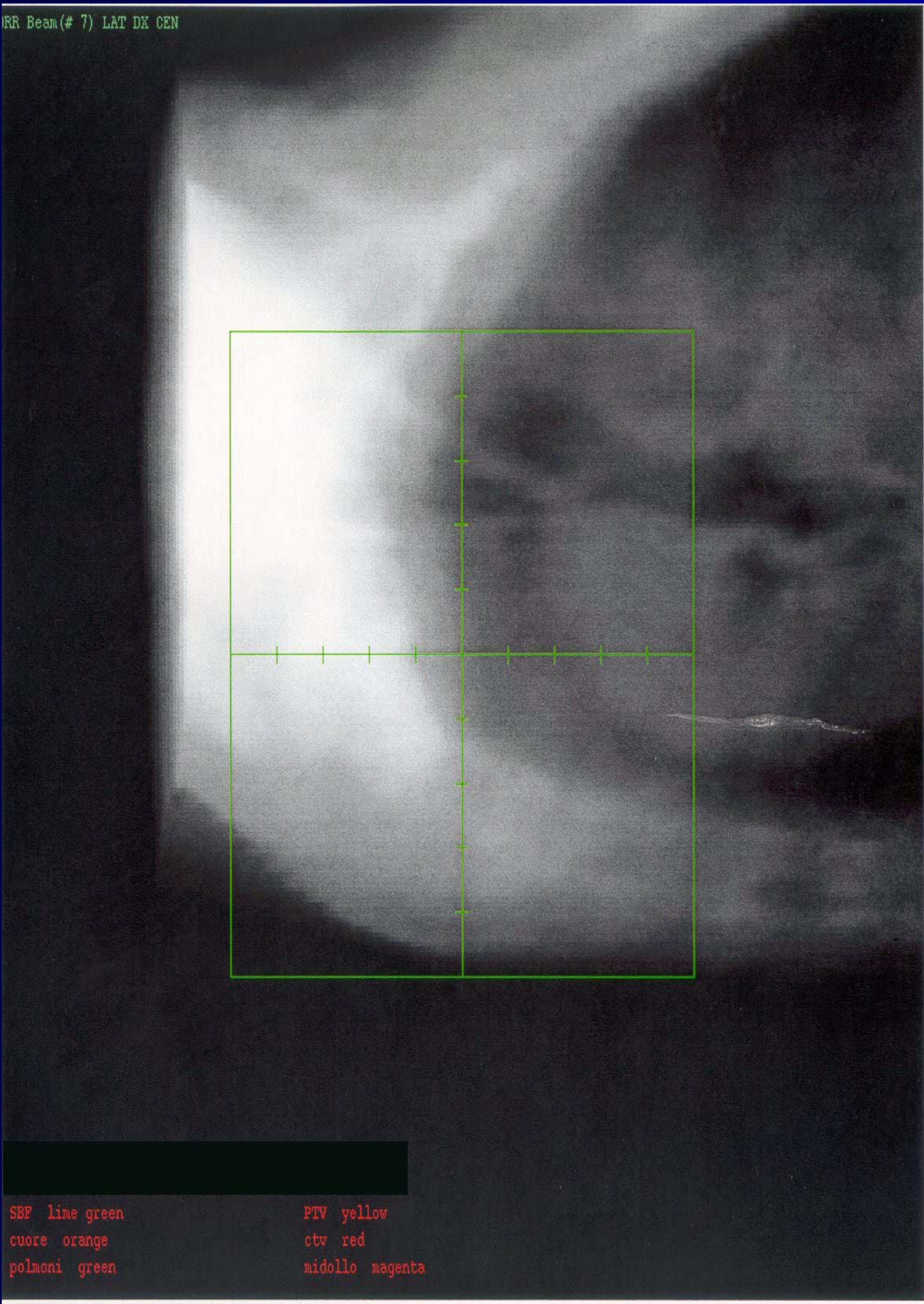
3 fractions

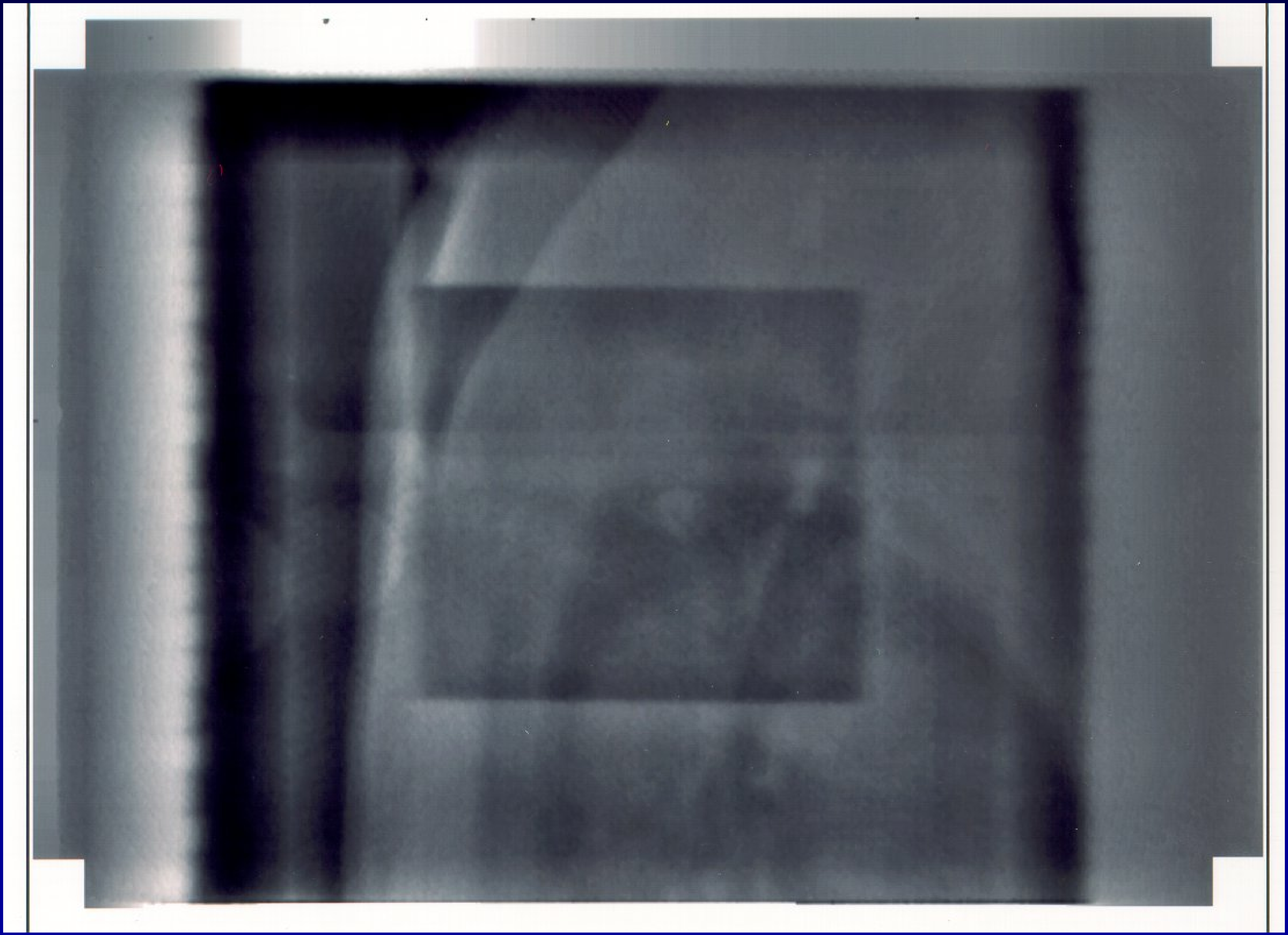
12 Gy / fraction to isocenter

10 Gy / fraction to 80% isodose


DRR Beam(# 6) ANT CEN
SBF lime green
cuore orange
polmoni green
PTV yellow
ctv red
midollo magenta




DRR Beam(# 7) LAT DX CEN
SBF lime green
cuore orange
polmoni green
PTV yellow
ctv red
midollo magenta



- Dose costraints to OAR were the following:

Lung: V12 < 20% Vol

Heart: < 3 – 3,5 Gy/fraction

Cord: < 3 – 3,5 Gy/fraction

Esophagus: < 4 Gy/fraction (< 1 cc > 95% dose)

- BED 3Gy to heart and to spinal cord was:

3 x 5 (1 + 3/ alfa/beta) = 30 Gy3

which corresponds to approximately to a total dose of 18 Gy with conventional fractionation

- Treatments were given daily.
- In all pts with more than one lesion treatment was performed in two different courses separated by a 2 weeks interval (dose distribution was however calculated as the sum of all treatments)
- V12 to lung ranged from 4,0% to 25,7% of volume
- Mean dose to lung ranged from 190 cGy to 789 cGy
- Total lung volume ranged from 2008 to 7660 cc (4 pts had already been submitted to pneumonectomy for a previous lung cancer)

STEREOTACTIC RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS
AT OSPEDALE BELLARIA

CTV (cc)		PTV (cc)	MLD (cGy)	V12%
< 20	range	18,8-71,4	190-496	5,1-12,8
	mean	41,6	298,6	8,1
20-50	range	71,3-116,4	206-614	4,0-17,1
	mean	88,5	389,9	11,1
> 50	range	118,8-231,6	335-789	5,9-25,7
	mean	126,1	531,1	14,5

STEREOTACTIC RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS AT OSPEDALE BELLARIA

Dose	Lesions	LC (%)*
3600 cGy / 3 fx.	36	32/36 (88.8%)#
5000 cGy / 5 fx	25	25/25 (100,0%)°

*Absence of progression in the irradiated volume

Follow up: 5-28 months; median f.u.: 16,4 months.

#14 patients relapsed in distant sites

°5 patients relapsed in distant sites (controlateral lung: 2 pts., brain: 2 pts., abdomen:1 pt.)


CT/e SYS#CT
Ex: 839
Se: 3
SN S48.00
Im: 7
DFOV 35.0cm
CHST
A 134
CASA DI CURA VILLA TORRI
Req Num:TORACE
M 80 839
DOB: 24 May 1921
14 Mar 2002
512
MF:1.1
Auto mA:MAX
5.00mm/8.00
Tilt: 0.0
W:1613 L:-485
P 184


Display/Image Registration 7.3.5
File View Zoom Tools
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Slice
326
RIGHT
LEFT
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HEAD
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POS
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RIGHT
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FOOT
File 1: p1462s0_BODY.img
Acq Date: 23 Apr, 2002
Name: VALTER LIPPARINI
Birth Date: 24 May, 1921
Id: 10931


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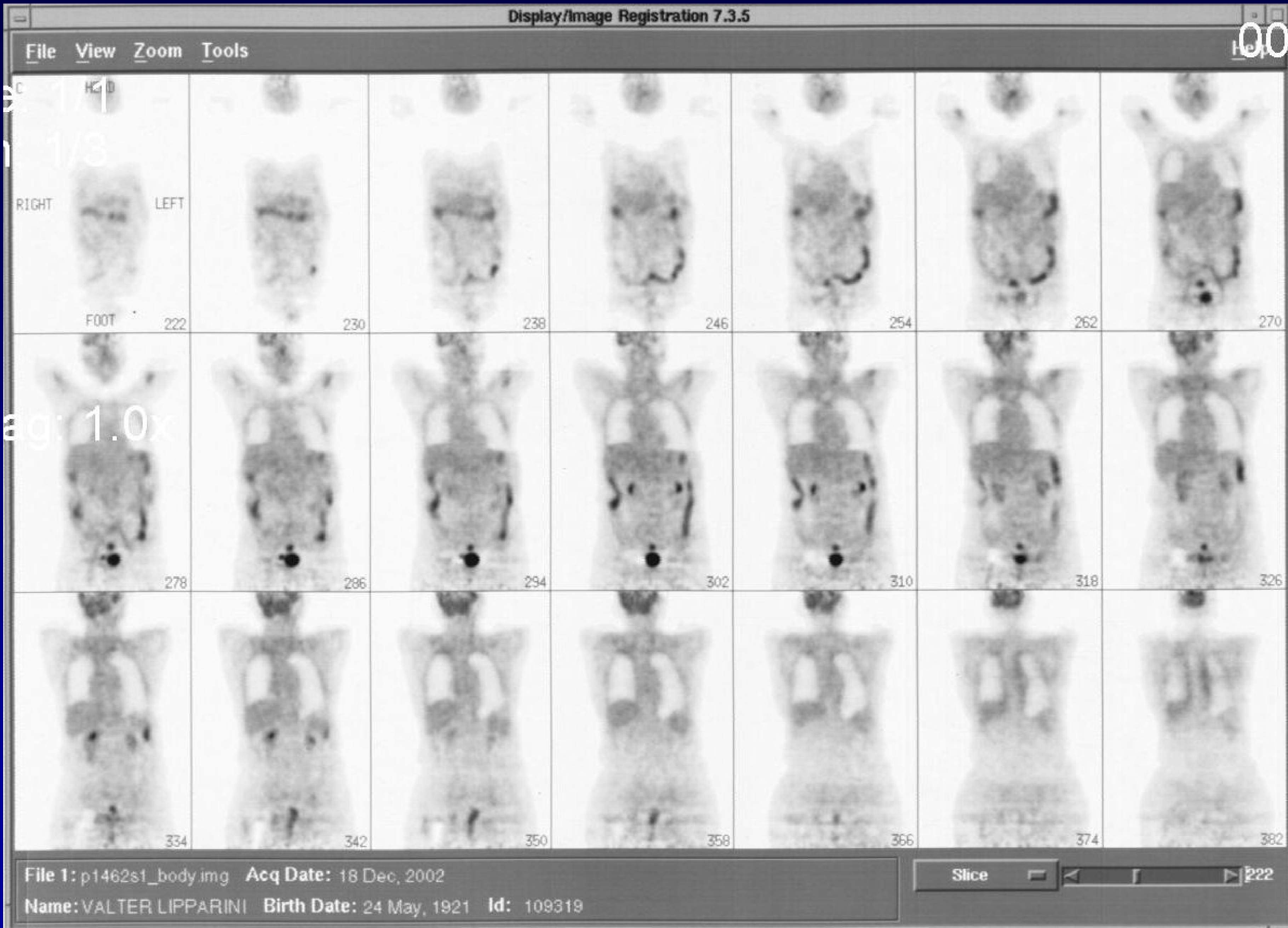
PAT2: 155688
ACC:
TC TORACE
06/12/2002
10:22:05
R
5 cm
1.13
CT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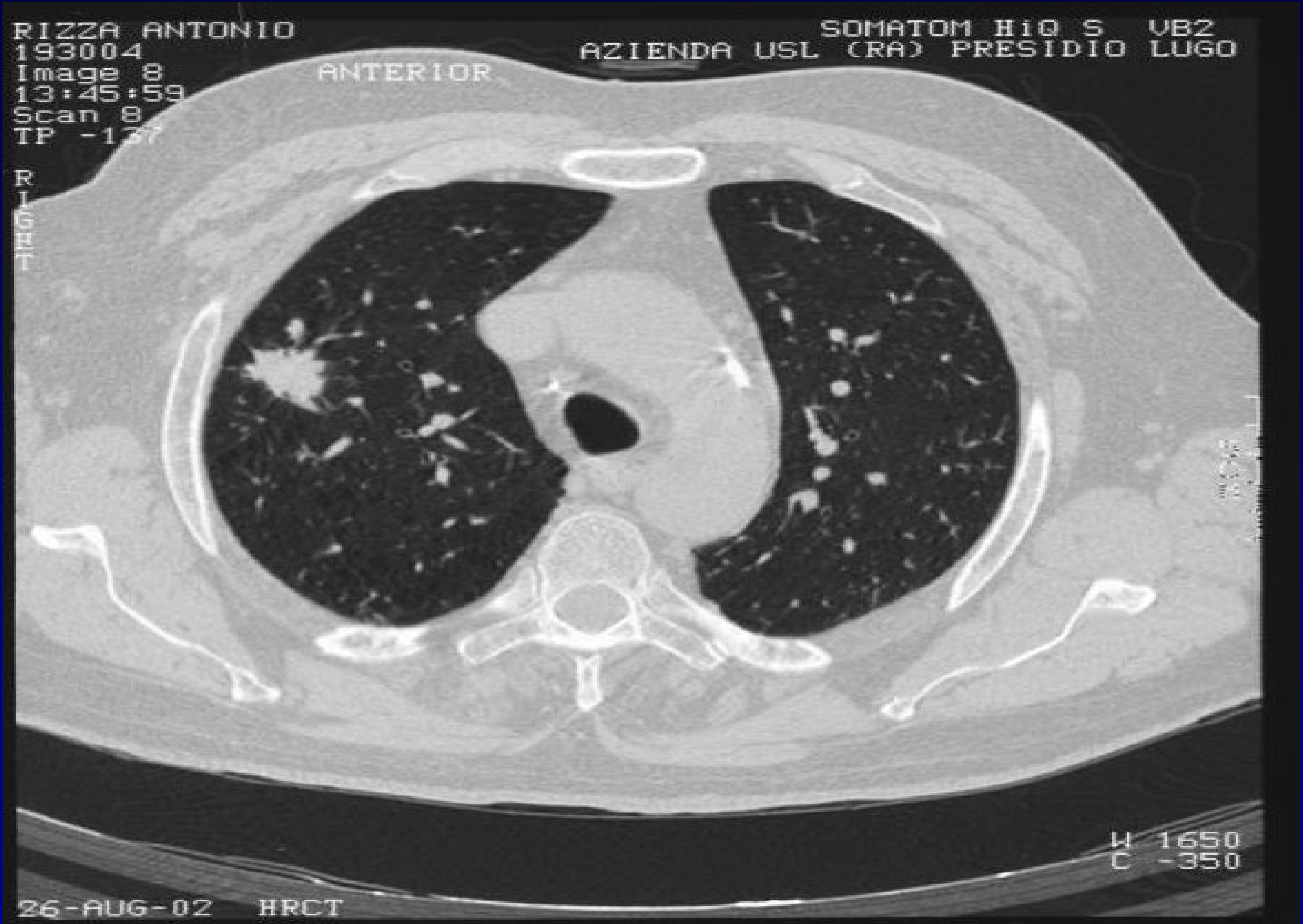

RIZZA ANTONIO
193004
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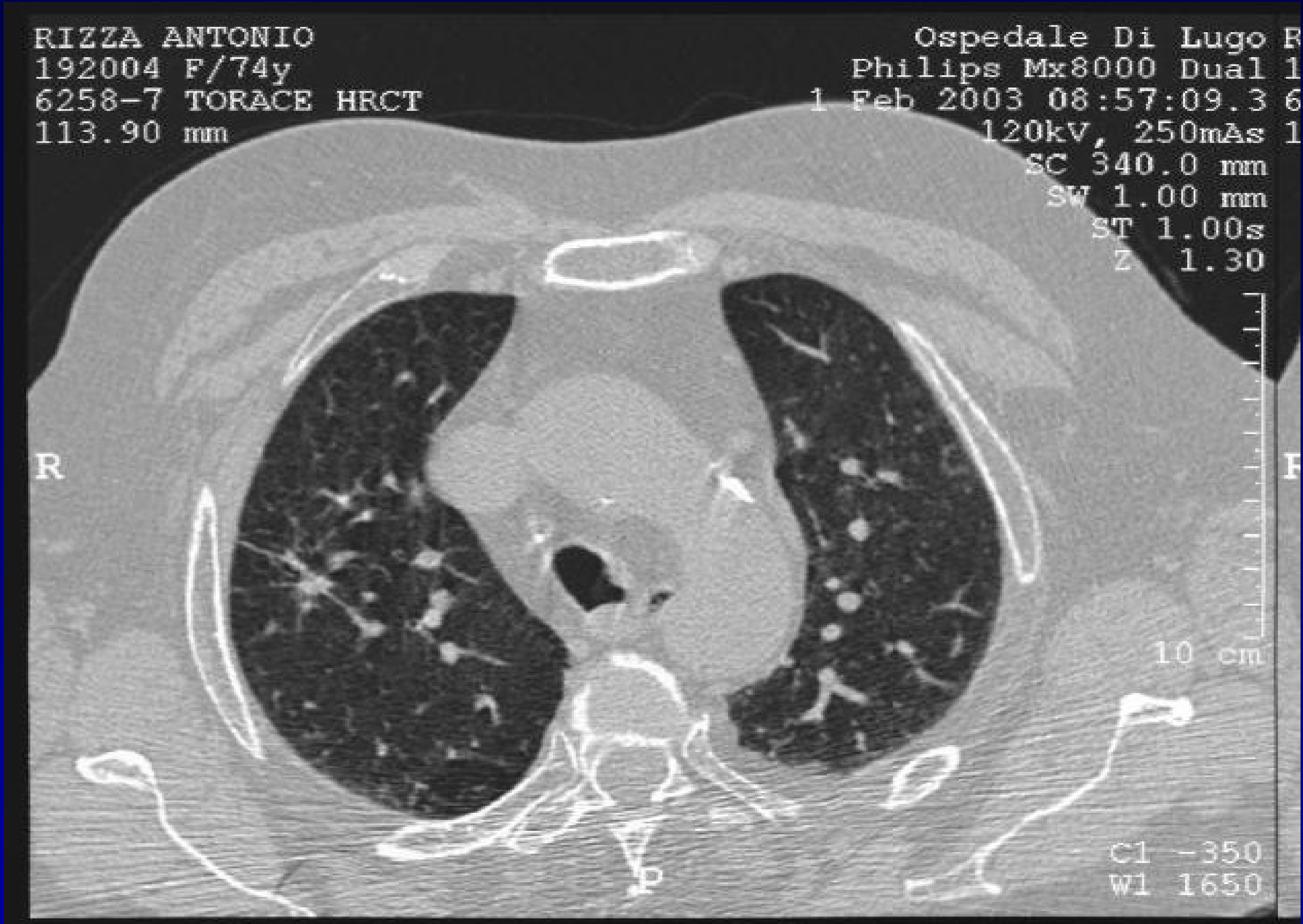
Scan 8
TP -137
SOMATOM HiQ S VB2
AZIENDA USL (RA) PRESIDIO LUGO
ANTERIOR
RIGHT
W 1650
C -350
26-AUG-02 HRCT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Ospedale Di Lugo
Philips Mx8000 Dual
1 Feb 2003 08:57:09.3
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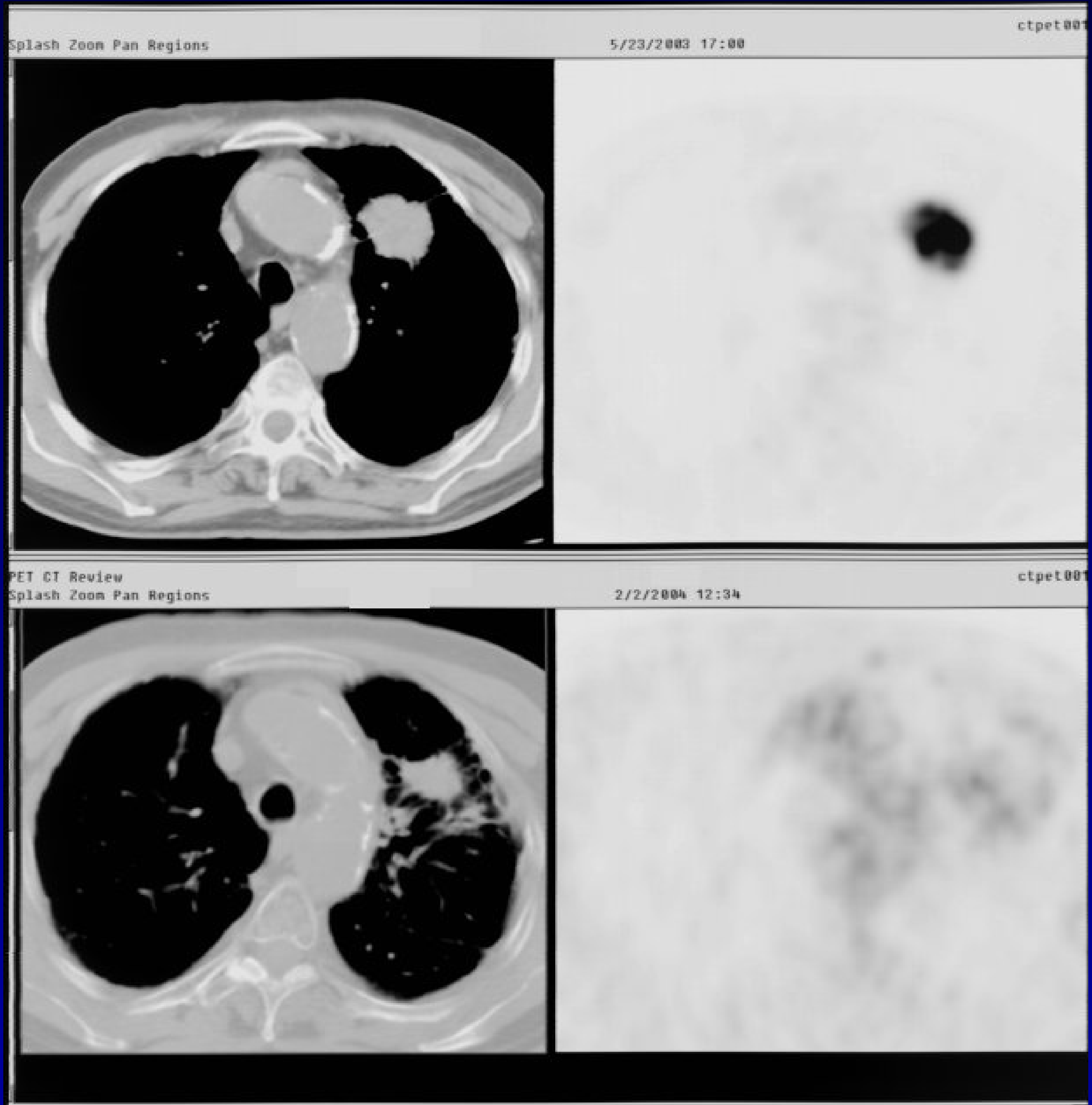
SC 340.0 mm
SW 1.00 mm
ST 1.00s
Z 1.30
R
10 cm
P
C1 -350
W1 1650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PET CT Review
ctpet001
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STEREOTACTIC RADIATION THERAPY IN LUNG TUMORS : *CONCLUSIONS*

- HYPOFRACTIONATED RADIOTHERAPY WITH STEREOTACTIC LOCALIZATION IN EARLY STAGE NSCLC AND IN SMALL SIZE SECONDARY LESION IS WELL TOLERATED

- HIGH DOSES (BED acute: 100 Gy 10) ARE NECESSARY TO ACHIEVE ACCEPTABLE RATES OF LOCAL CONTROL

- NO SIGNIFICANT TOXICITY HAS BEEN OBSERVED AT THE DOSE AND DOSE /VOLUME LIMITS DESCRIBED BEFORE

RADIATION THERAPY IN LUNG TUMORS: *CONCLUSIONS*

- PROBLEMS THAT LIMIT A FURTHER DOSE ESCALATION ARE REPRESENTED BY:

  A MORE ACCURATE DEFINITION OF GTV

  AN IMPROVEMENT IN TREATMENT REPRODUCIBILITY AND IN CONTROL OF BREATHING (IMAGE GUIDED RT, BREATH CONTROL DEVICES)

- THERE IS NO EVIDENCE ABOUT THE BEST FRACTIONATION SCHEME , AND FURTHER STUDIES ARE NECESSARY TO DEFINE THE ROLE OF HYPOFRACTIONATED TECHNIQUES

valutazione dell'impatto del riposizionamento sulla distribuzione di dose sul CTV: adeguatezza dei margini CTV → PTV

controllo della adeguatezza dei margini CTV → PTV (5 mm nel piano assiale – 10 mm longitudinalmente)

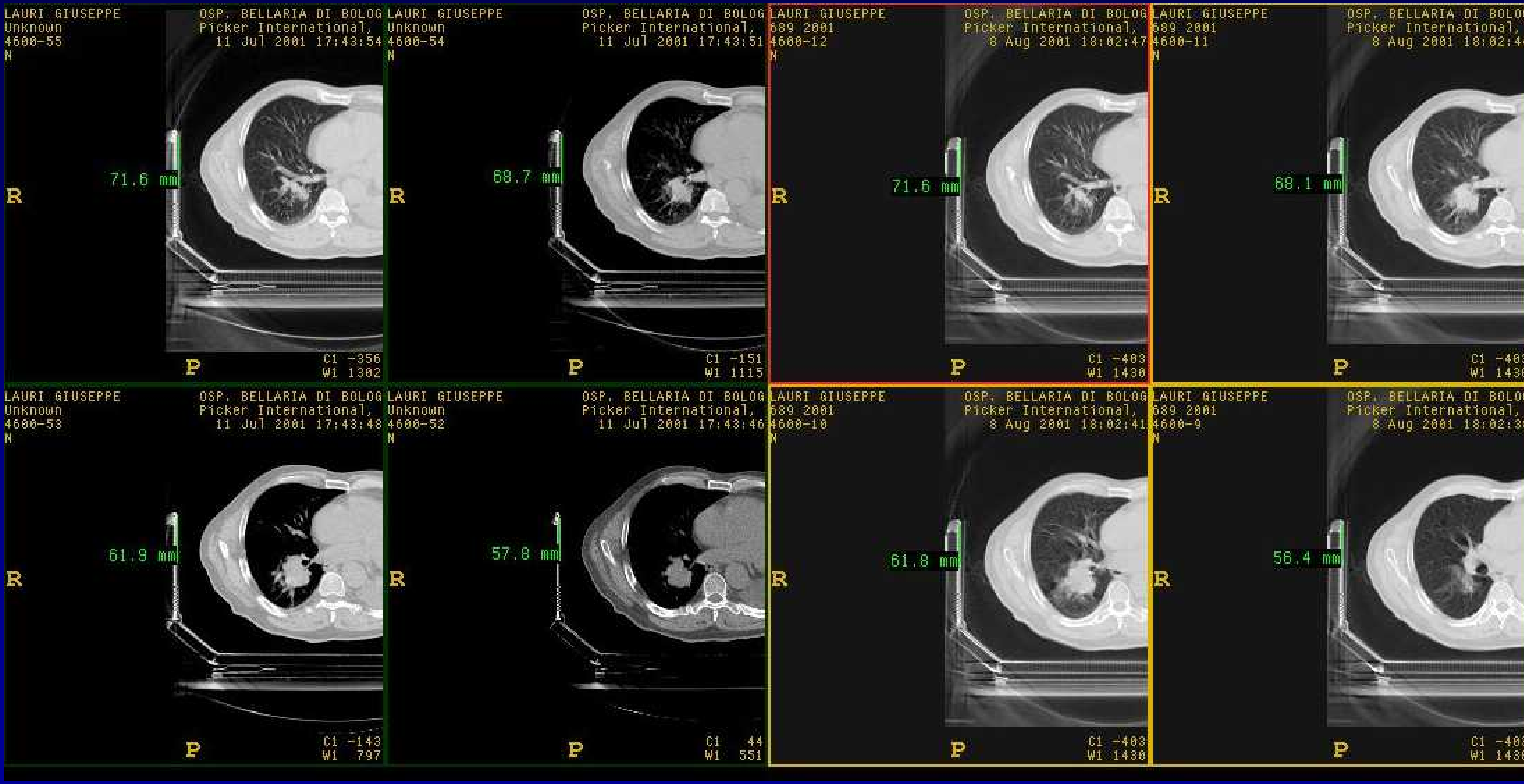
Si è impiegato un CRITERIO DOSIMETRICO: Copertura del CTV dalla isodose di riferimento (80 %) successivamente al ri-posizionamento del paziente nel b.f. con la seguente procedura:

Per i primi 12 pz (14 bersagli) da Apr 2001 a Dic 2002, dopo avere elaborato e accettato un piano di trattamento :

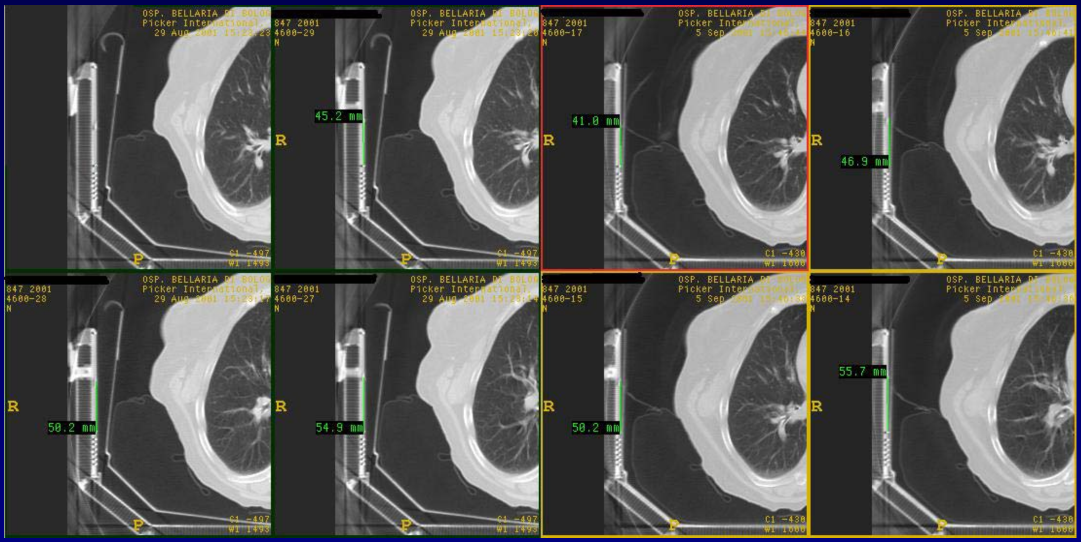
- **seconda acquisizione CT (3 mm spessore)**
- **nuova delineazione del GTV_{sim} (lo stesso medico seguendo un protocollo definito)**
- **definizione di CTV_{sim} sul TPS**
- **individuazione dell' isocentro relativamente al b.f. (per mezzo delle coordinate stereotassiche trovate nel piano di trattamento)**
- **fasci del piano approvato sulla posizione dell'isocentro**
- **valuazione del DVH del CTV_{sim}**

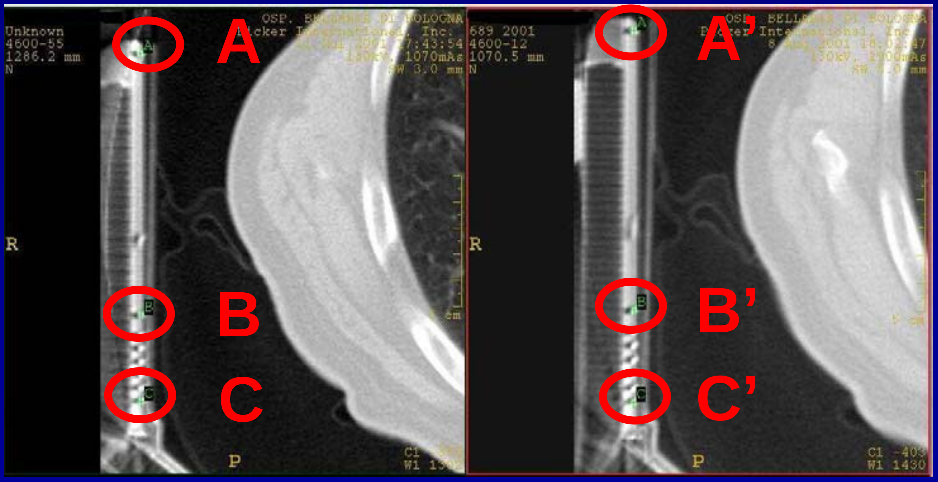
Prima serie CT

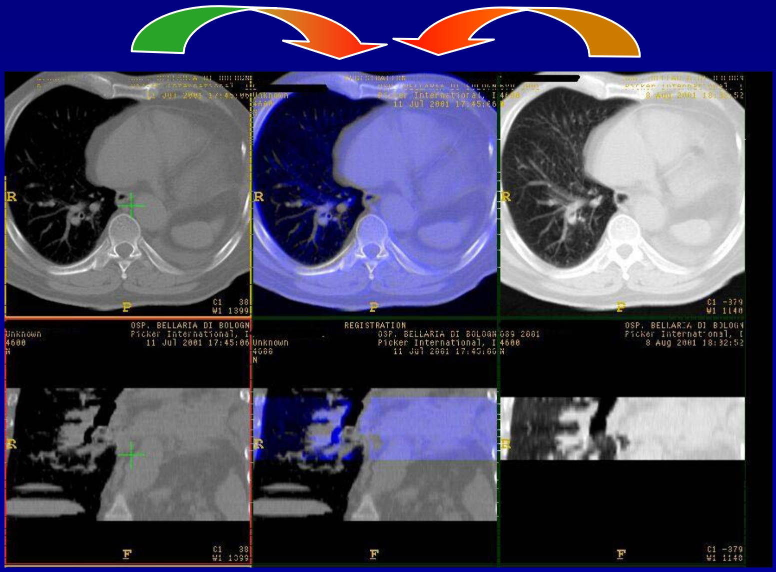
Seconda serie CT



valutazione dell'impatto del riposizionamento sulla distribuzione di dose sul CTV: adeguatezza dei margini CTV → PTV

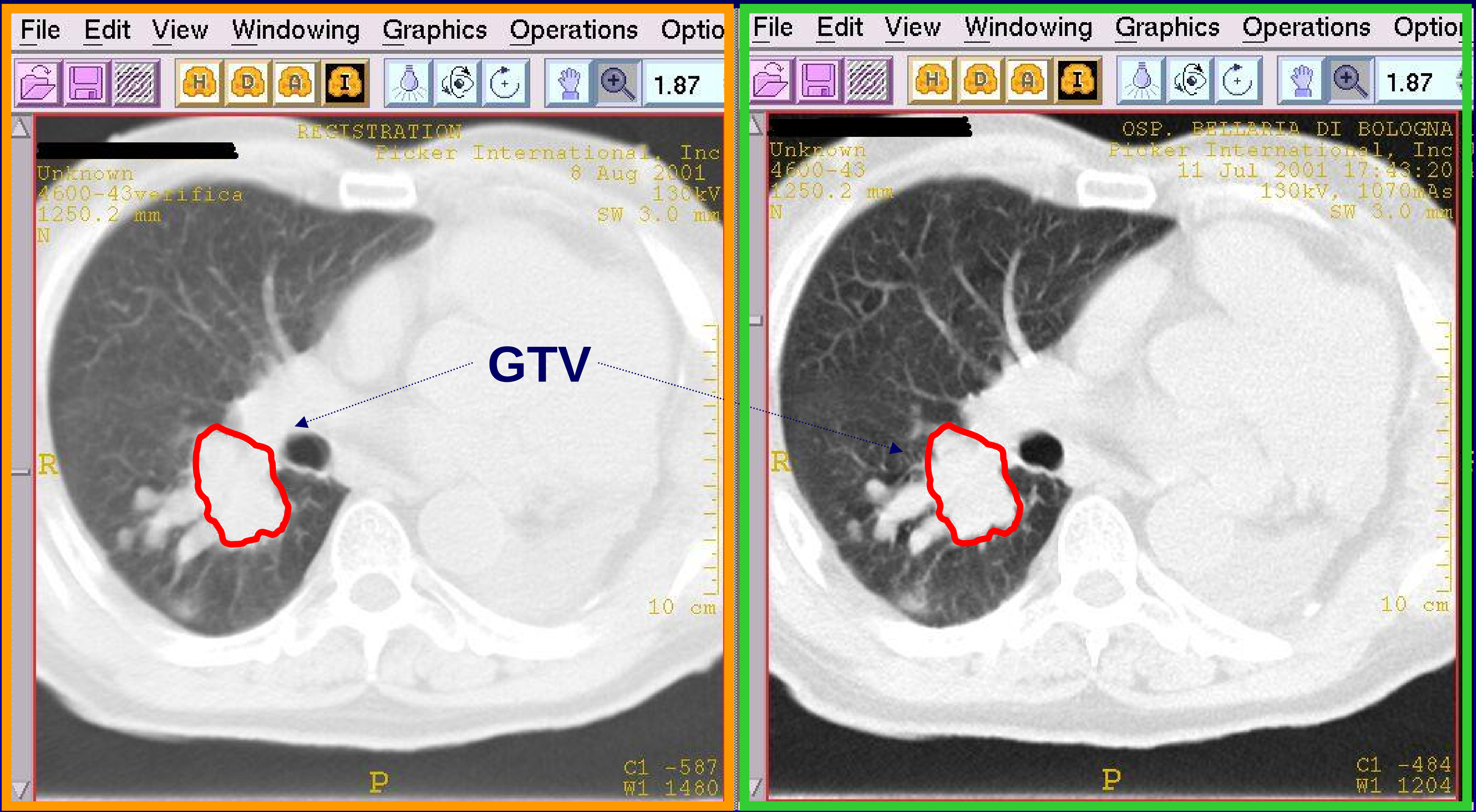




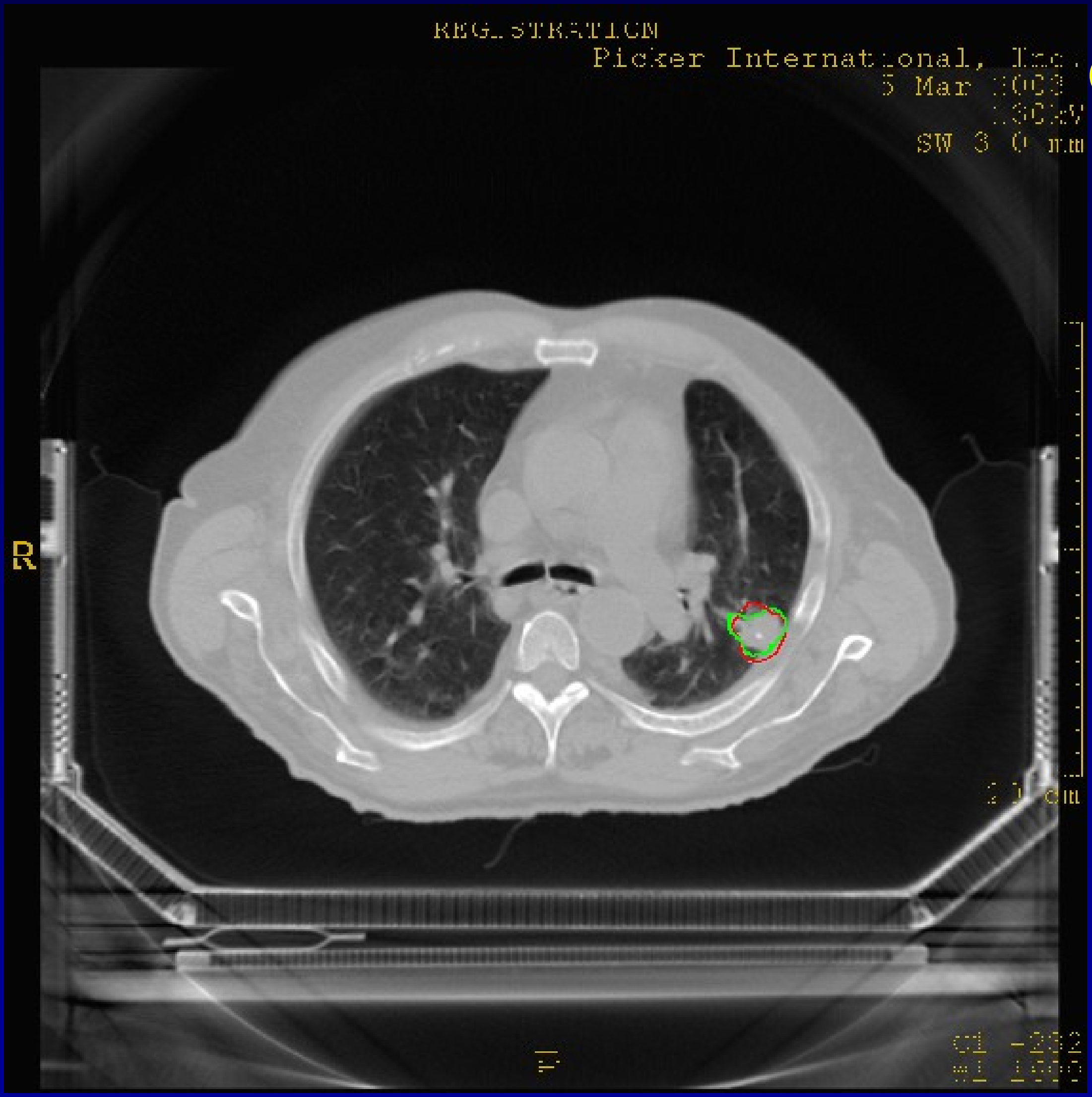


valutazione dell'impatto del riposizionamento sulla distribuzione di dose sul CTV: adeguatezza dei margini CTV → PTV

(2° CT) **(1° CT)**



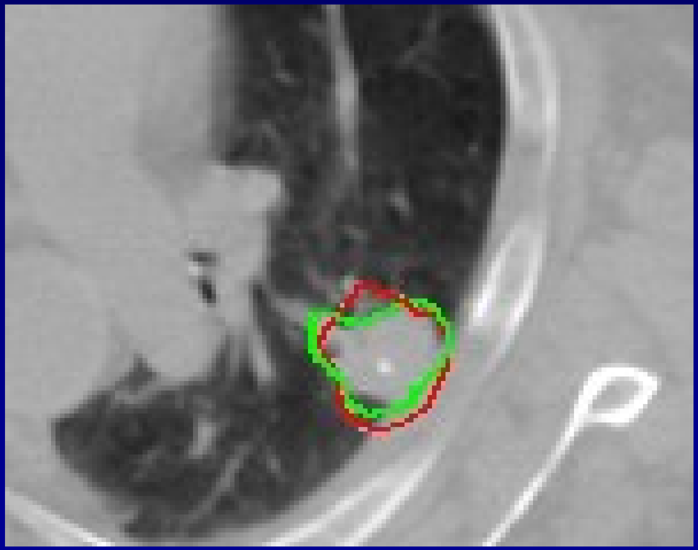
valutazione dell'impatto del riposizionamento sulla distribuzione di dose sul CTV: adeguatezza dei margini CTV → PTV



CT_{sim}

— GTV

— GTV_{sim}



Radiotherapy and Oncology 66 (2003)

"Impact of target reproducibility on tumor dose in stereotactic radiotherapy of target in the lung and liver"

J. Wulf et al (Univ. Of Würzburg)

TC (Target Coverage)

TC = % of CTV all'interno della isodose di riferimento

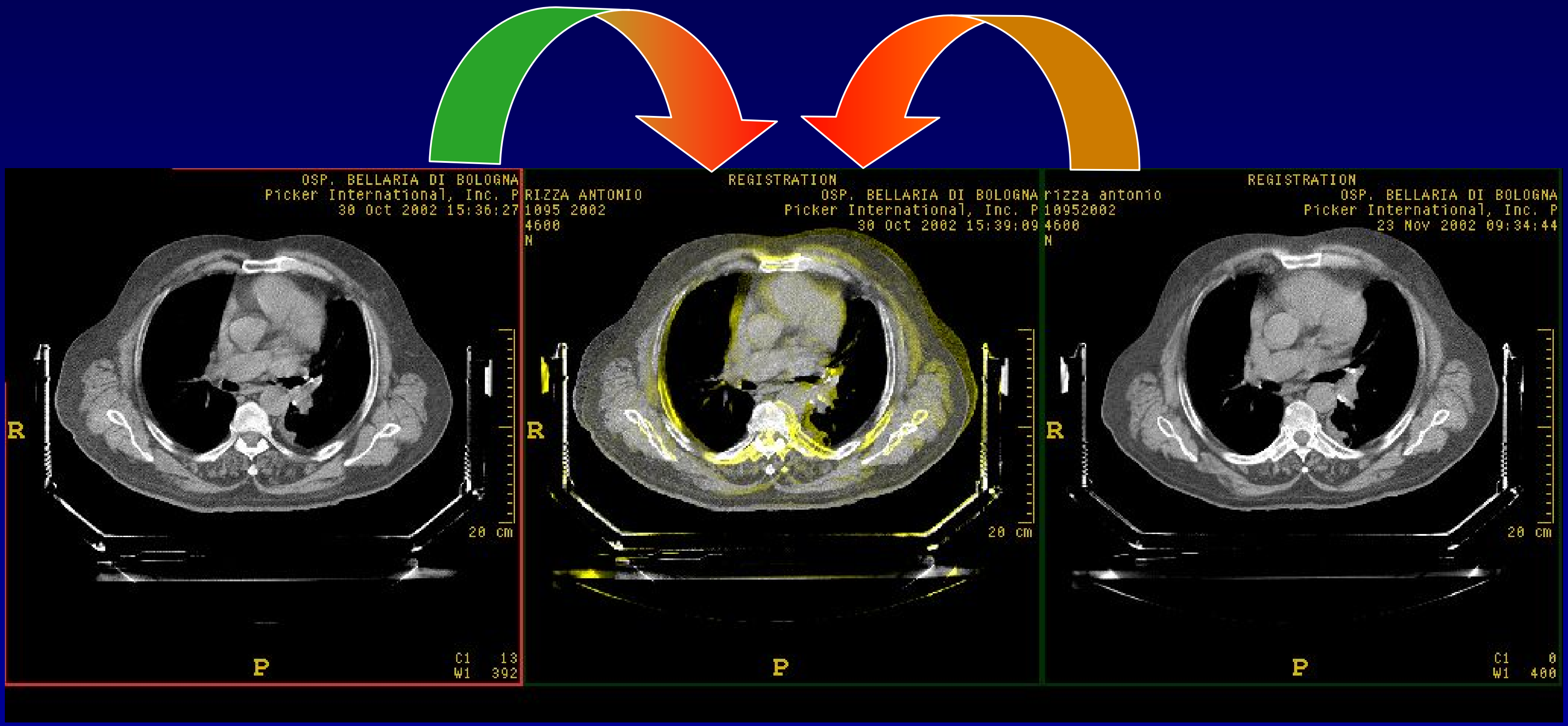
N° 2/14 targets with TC^{sim} < 95%

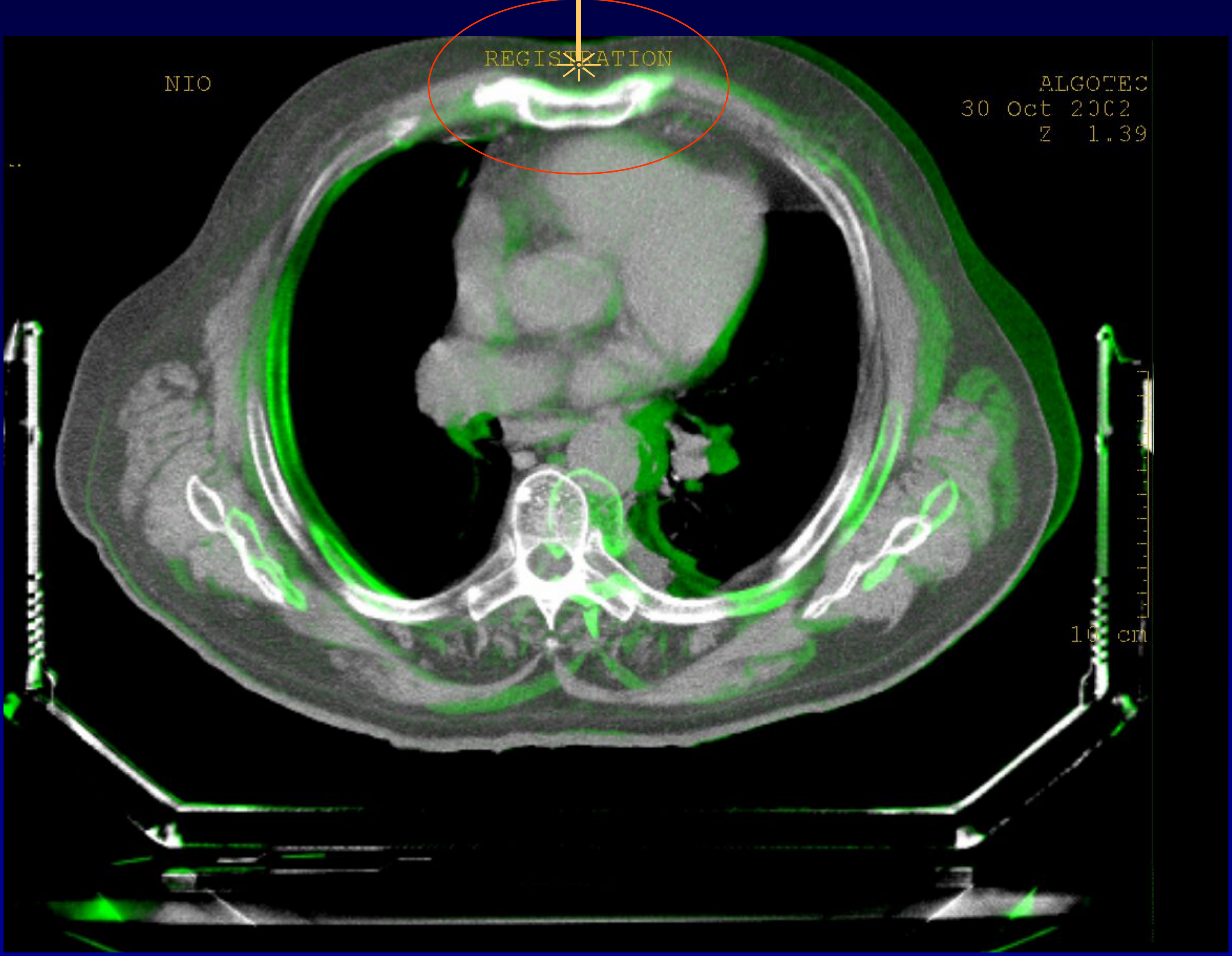
N° 1/14 targets with TC^{sim} < 85%

TC^{sim}

TC^{sim}_{mean}	0,958
TC^{sim}_{median}	0,996
TC^{sim}_{min}	0,682
Tc^{sim}_{max}	1,000
SD_{TCsim}	0,084

Confronto delle posizioni del paziente all'interno del b.f.





Presence of <u>rotation and traslation</u> of the patients with respect to SBF


REGISTRATION
RIZZA ANTONIO
OSP. BELLARIA DI BOLOGN
1995 2002
Picker International, I
4600
30 Oct 2002 15:39:09
N
R
F


REGISTRATION
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30 Oct 2002 15:39:09
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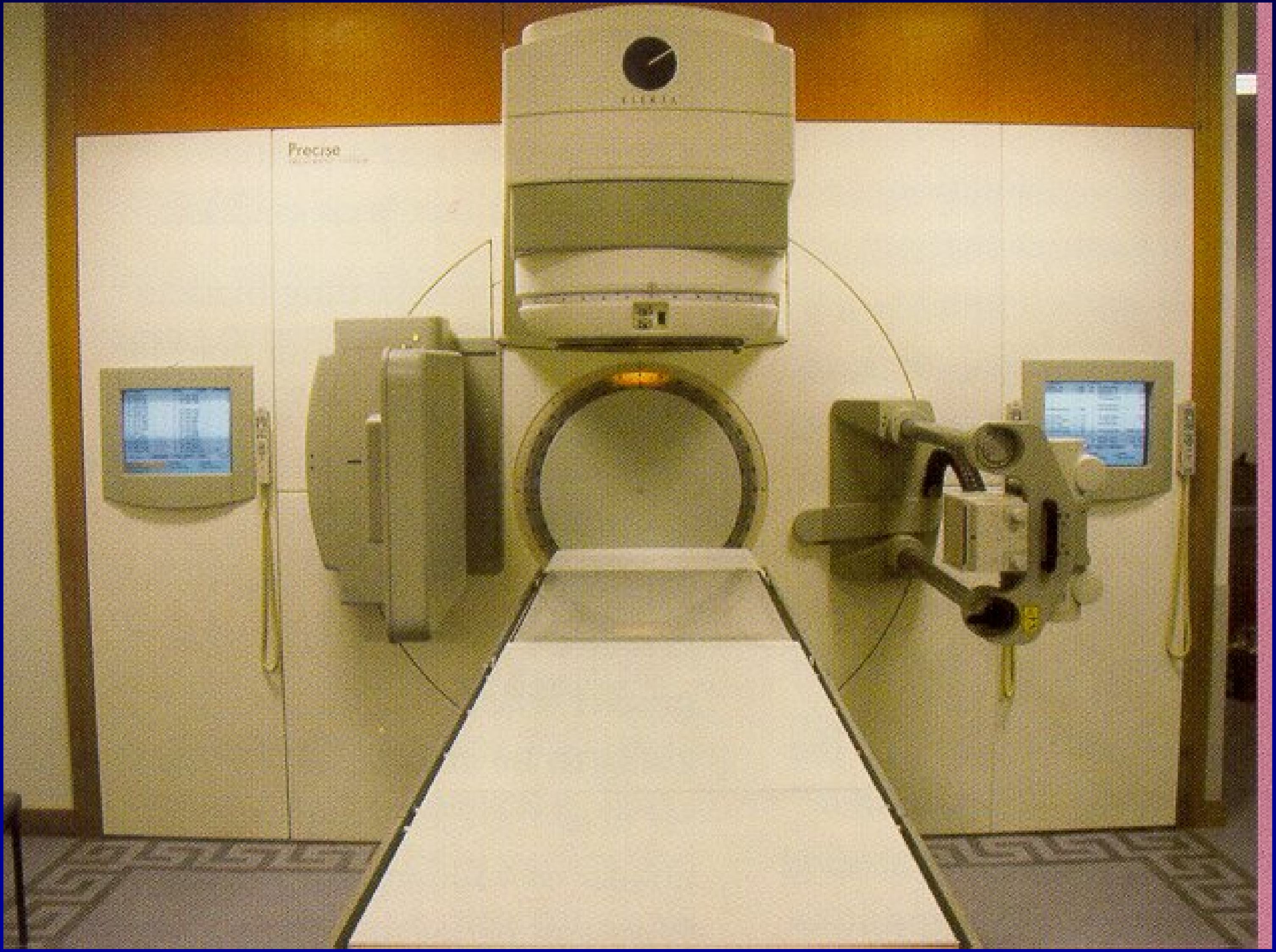
A


Precise

Trattamenti radioterapici ipofrazionati effettuati mediante “body frame”

CONCLUSIONI

nella nostra esperienza :

- **sono trattamenti di radioterapia conformazionale di buona accuratezza**
- **risulta praticamente possibile irradiare con l’isodose di riferimento volumi che sono notevolmente conformati al volume bersaglio**
- **è di conseguenza possibile risparmiare gli organi sani circostanti meglio che nei trattamenti effettuati con tecniche convenzionali. A tal fine:**

  a) è necessario aggiungere margini da CTV a PTV che risultano inferiori ai margini che vengono aggiunti nei trattamenti effettuati con tecniche convenzionali

  b) risulta di estrema importanza un corretto riposizionamento del paziente all’interno del body frame

Salvatore .G. aa 78 sesso maschile

Diagnosi aprile 03: carcinoma epidermoide del lobo polmonare superiore sinistro, diametro 4,2 cm, non adenopatie mediastiniche, T2 N0, non operabile per elevato rischio anestesiologico (BPCO, esiti di IMA, aneurisma aorta addominale.

Tc esordio (15/04/03): formazione espansiva del diametro di circa 4,2 cm a margini spiculati a livello del lobo superiore di sinistra. Tale formazione prende contatto con la parete toracica senza sicuri aspetti infiltrativi. Non sono apprezzabili adenopatie mediastiniche di diametro trasversale superiore a 1 cm

Broncoscopia: negativa

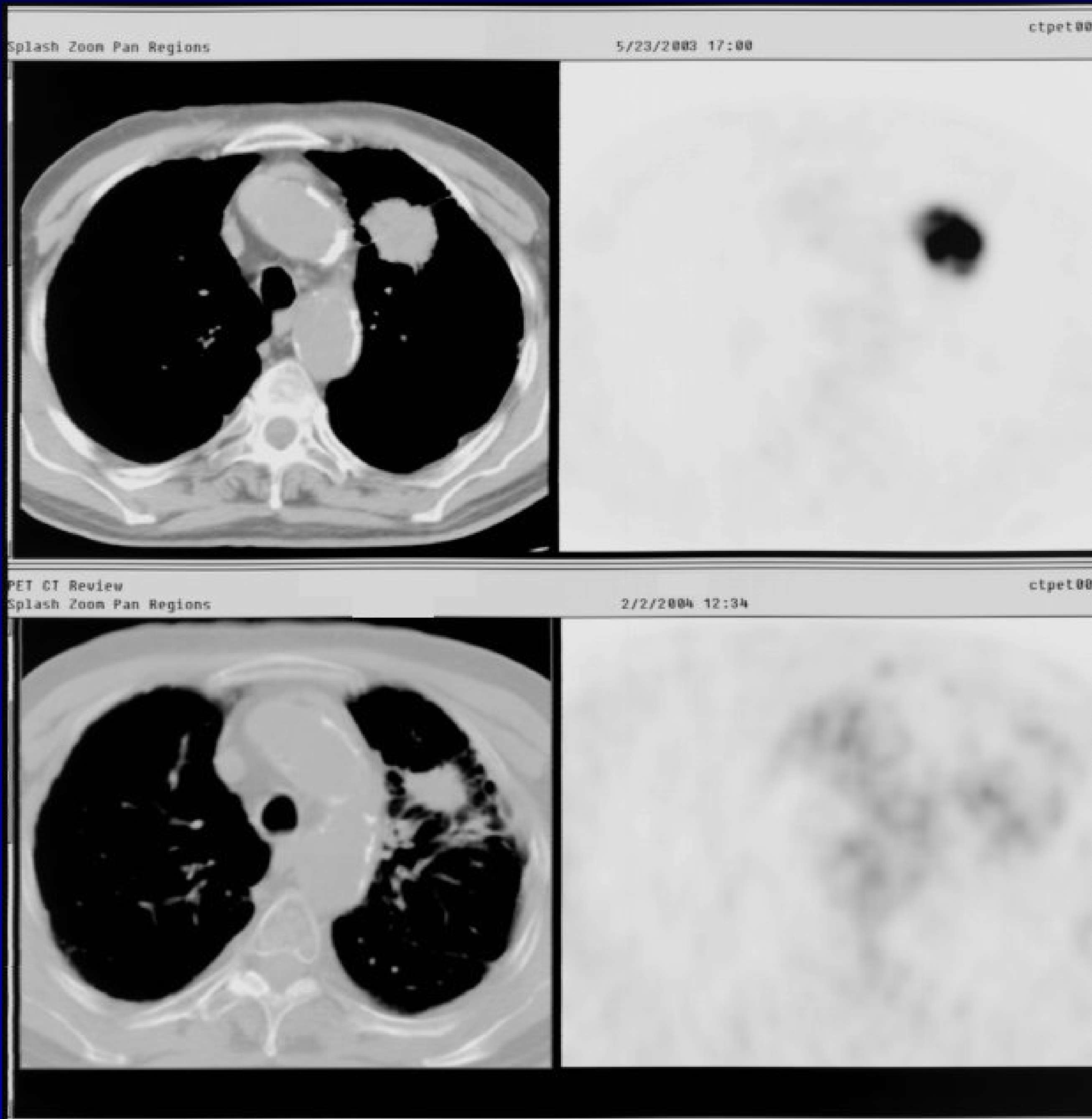
PET (23/05/03): iperfissazione al terzo superiore del polmone sinistro, assenza di ipercaptazione a livello mediastinico e negli altri distretti corporei esaminati…….

Radioterapia Luglio 2003: 50 Gy / 5 frazioni sulla lesione polmonare sinistra con localizzazione stereotassica

Tc (28/10/03): riduzione della neoformazione; esiti attinici

PET (02/02/04): scomparsa dell'area di ipercaptazione: risposta completa alla terapia

Maggio 2004: Il Paziente è attualmente vivo e libero da malattia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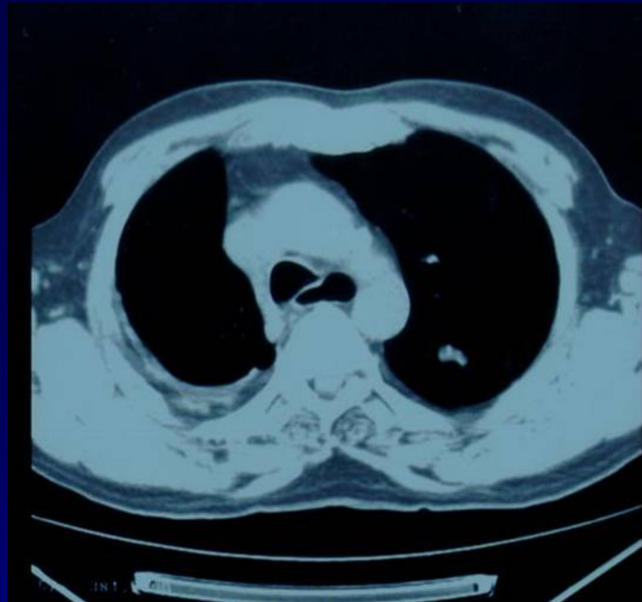
Splash Zoom Pan Regions
5/23/2003 17:00
PET CT Review
ctpet00
Splash Zoom Pan Regions
2/2/2004 12:34

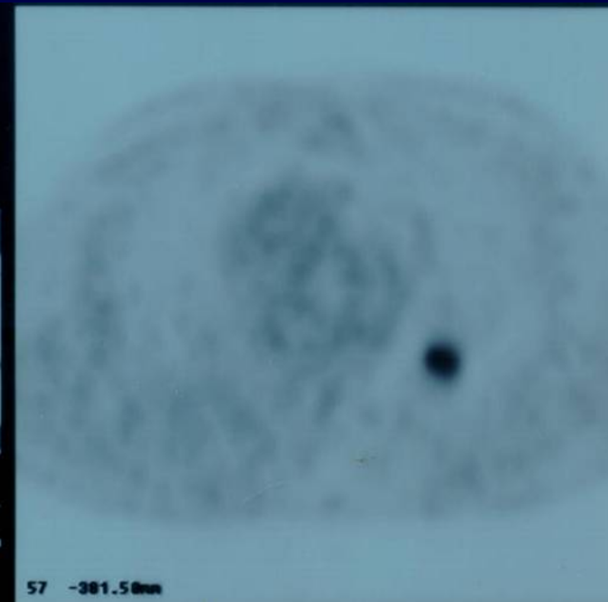
Armando N.   aa 78   sesso maschile

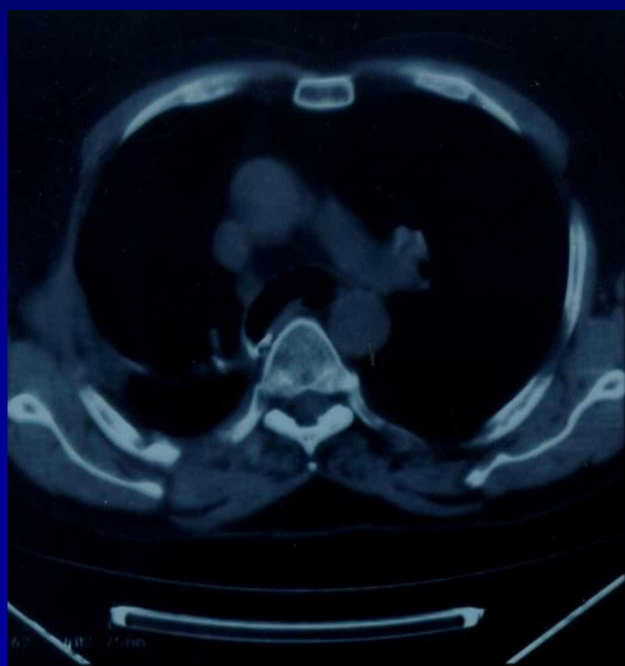
Diagnosi Ottobre 02: adenocarcinoma del lobo polmonare   superiore destro, diametro 3 cm, non adenopatie mediastiniche,
T1 NO: lobectomia superiro destra e linfadenectomia ilo mediastinica (linfonodi 10 R, 7, 4R, 2R): pT1 N1.

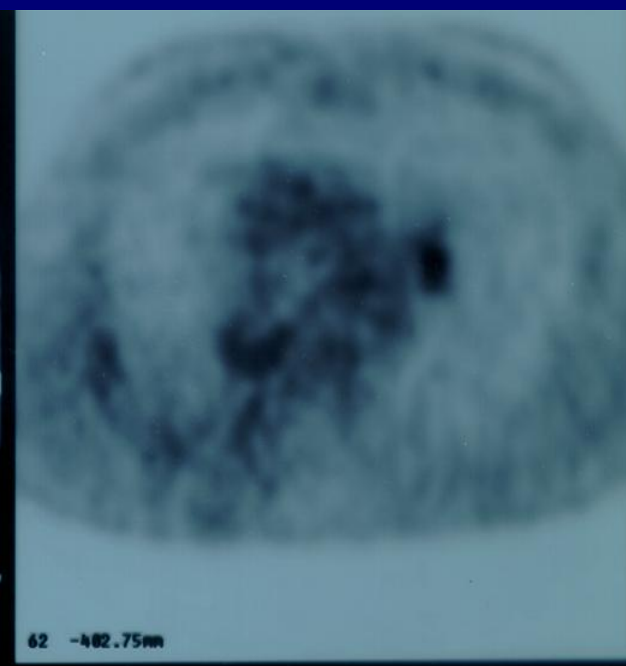
Tc controllo (03/03/04): formazione espansiva del diametro di circa 1,8 cm a margini spiculati a livello del lobo superiore di sinistra. Non sono apprezzabili adenopatie mediastiniche di diametro trasversale superiore a 1 cm

PET (21/04/04): iperfissazione al terzo superiore del polmone sinistro, area iperattiva a livello dell'ilo polmonare sinistro, assenza di ipercaptazione a livello mediastinico e negli altri distretti corporei esaminati…….




57 -381.50mm




62 -402.75mm

RADIATION THERAPY IN THE TREATMENT OF LUNG TUMORS:
UNCERTAINTIES IN DEFINING CTV

COVERAGE OF OPTIMAL PTV (95% ISODOSE) AND RESULTING V 20

Lack of coverage (%)

Slow CT + 5 mm	A	B	C	D	E	F	G
CTV	0,0	0,0	0,0	0,0	0,0	1,3	0,0
Fast CT							
CTV	0,0	4,3	0,0	1,8	0,2	0,0	3,5

V 20 (%)

	A	B	C	D	E	F	G
V 20 slow	10,7	7,0	11,5	21,4	13,5	15,6	30,6
V 20 optimal	9,4	5,3	9,1	19,0	11,9	13,9	27,7

da: van Sornsen de Koste, IJROBP, 2003

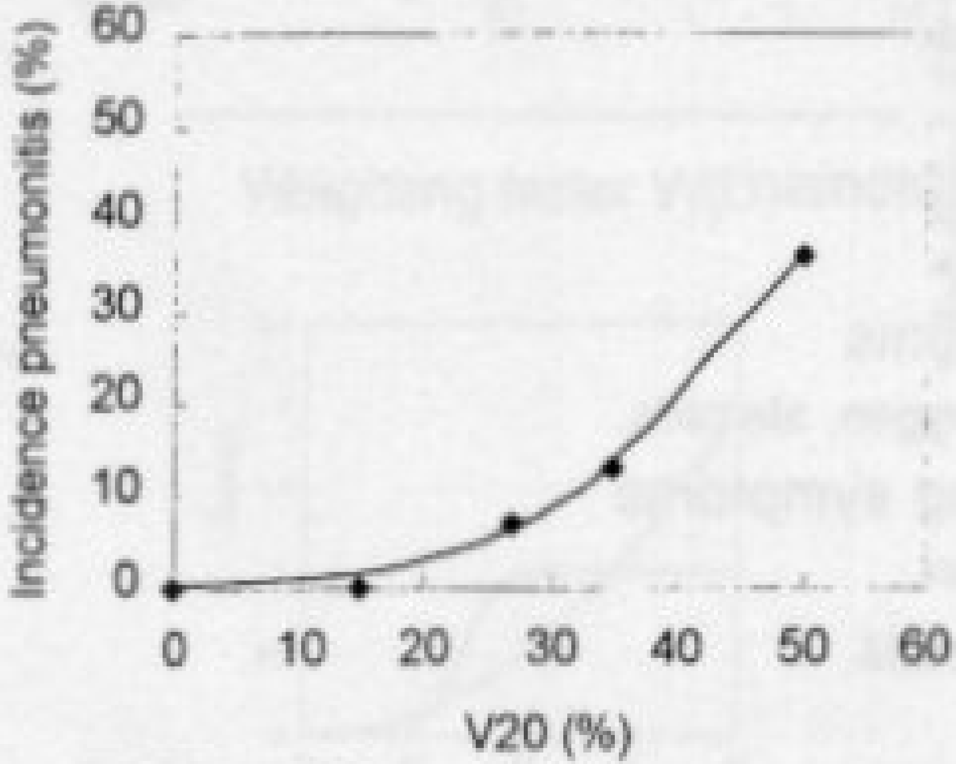
Reasons for limited success of dose escalation studies in non small cell lung cancer

- Radiation resistance of tumor stem cells and clonogens to conventional dose levels of 60 to 70 Gy
- Dosimetric uncertainties - tumor dose estimated from selected 2D planar dose calculations
- Tumor dose restricted due to inclusion of large normal tissue safety margins to compensate for dosimetric uncertainties

Why is it Necessary to Improve Local Tumor Control?

- Local control is a prerequisite for cure
- Local failure may affect quality of life
- Local failure is associated with an increase in metastatic disease

Radiation pneumonitis and V_{20}



Graham et al., IJROBP, 1999

NKI
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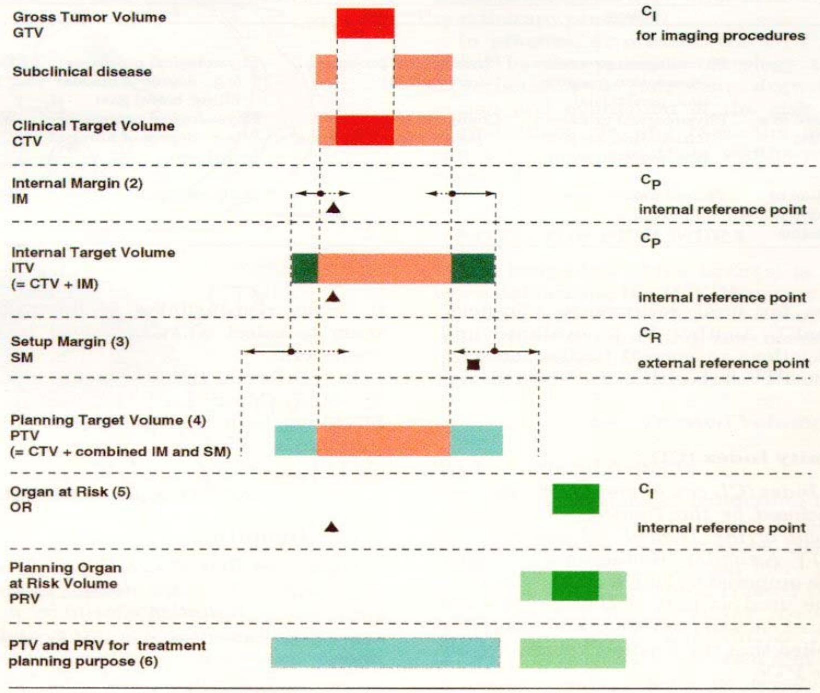

Fig. 2.14. Schematic representation of the different volumes/margins.

Notes:

(1) For explanation, see Sections 2.1–2.7.
(2) The Internal Margin may be asymmetrical.
(3) Like the Internal Margin, the Set-up Margin may also be asymmetrical.
(4) To delineate the PTV, the IM and SM are not added linearly (since this could result in an excessively large PTV), but are combined essentially subjectively (for explanation, see text). The PTV is thus smaller than if one would simply have added the IM and SM linearly.
(5) For Organs at Risk (OR), margins are added in the same way as for the PTV.
(6) The PTV and PRV may or may not overlap.

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IM

SM

IM + SM
↓
PTV

1. Implicazioni nella fase di planning