

LA RADIOTERAPIA DELLE OLIGOMETASTASI POLMONARI

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Radioterapia Oncologica
Taranto

LA RADIOTERAPIA
PALLIATIVA CON
TECNICHE SPECIALI
DELLA MALATTIA
METASTATICA

COSENZA
28 giugno 2013

COORDINATORE DEL CORSO

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Radioterapia delle oligometastasi polmonari

- Incidenza e tipologia
- Razionale e Indicazioni
- Frazionamento e Tecniche di irradiazione
- Organi a rischio e limiti di dose
- Risultati
- Complicanze
- Ottimizzazione dei trattamenti
- Conclusioni

Incidenza

- colon-retto 10% Goya T, 1989; McCormak PM, 1992
- mammella 19% (M1) Hanrahan EO, 2005
- sarcomi 20→50% Treasure T, 2012
- seminoma (mediastino) 10% (pre CT)
- melanoma 13%
- uroteliale e ginecologico 5%
- tiroide (papillare) 7%
- polmone (metastasi o II primitivo)

Tipologia

- colon-retto 78%
- sarcomi 17%
- mammella 11%
- seminoma
- melanoma
- uroteliale e ginecologico
- tiroide
- polmone (metastasi o II primitivo)

Predictor variables	Overall (%)	Alive (%)	Death (%)	P value
No. of patients	164 (100)	77 (46.95)	87 (53.05)	
Sex				
Male	100 (60.98)	48 (62.34)	52 (59.77)	0.7
Female	64 (39.02)	29 (37.66)	35 (40.23)	
Age (mean ± SD)	64.17 ± 14.4	65.18 ± 13.98	63.27 ± 14.78	0.4
Histology				
Sarcoma	28 (17.07)	11 (14.29)	17 (19.54)	0.2
Melanoma	7 (4.27)	4 (5.19)	3 (3.45)	
Germ cell tumors	3 (1.83)	0	3 (3.45)	
Epithelial	126 (76.83)	62 (80.52)	64 (73.56)	
Colorectal	99 (78.57)	51 (82.26)	48 (75)	0.4
Breast	14 (11.11)	5 (8.06)	9 (14.06)	
Urothelial	3 (2.38)	1 (1.61)	2 (3.13)	
Gynecological	2 (1.59)	2 (3.23)	0	
Head-neck	8 (6.35)	3 (4.84)	5 (7.81)	

Razionale

The International Registry of Lung Metastases: Long-term results of lung metastasectomy: prognostic analyses based on 5206 cases. *J Thorac Cardiovasc Surg* 1997, **113**(1):37–49.

Sopravvivenza 36% a 5 anni nei completamenti resecati

Rusthoven KE, Kavanagh BD, Burri SH, Chen C, Cardenes H, Chidel MA, Pugh TJ, Kane M, Gaspar LE, Schefter TE: Multi-institutional phase I/II trial of stereotactic body radiation therapy for lung metastases. *J Clin Oncol* 2009, **27**(10):1579–1584.

Controllo locale e sopravvivenza a 2 anni: 96% e 39%

(1→3 metastasi)

Indicazioni

- 1→3 (5) ripetizioni
- Diametro max 4cm
- Tumore primitivo controllato
- Assenza di ripetizioni in altre sedi
- Istologia favorevole
- Latenza tra primitivo e metastasi
- Giovane età
- Buon PS

Rubin P et al, Semin Radiat Oncol 2006

Norihisa Y et al, IJROBP 2008

Nagata Y et al, IJROBP 2011

Caratteristiche della irradiazione

- **Stereotassi**

elevata conformazione delle curve di dose al volume bersaglio con ripido gradiente di dose rispetto agli organi critici vicini al bersaglio

- **Ridotto volume del PTV**

- **Ipofrazionamento: 1 → 10**

danno al microcircolo per apoptosi endoteliale

- **Trattamento di una o più lesioni contemporaneamente**

riduzione del tempo complessivo della RT

i volumi di trattamento

– Primitivi: GTV = Tumore

ITV = CTV (tumore + microinfiltrazione (5 mm))
+ escursione respiratoria

PTV = ITV + errore di riposizionamento

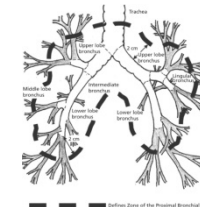
– Secondari: GTV, ITV e PTV

Frazionamento

Risultati migliori con $BED_{10} \geq 100$

Onimaru R, IJROBP 2003; Guckenberger M, IJRBO 2009

- Lesioni centro-polmonari: 15 -20 Gy x 3
- Lesioni adiacenti la parete: 12 Gy x 5
- Lesioni in prossimità di bronchi e grossi vasi: 7,5 Gy x 8

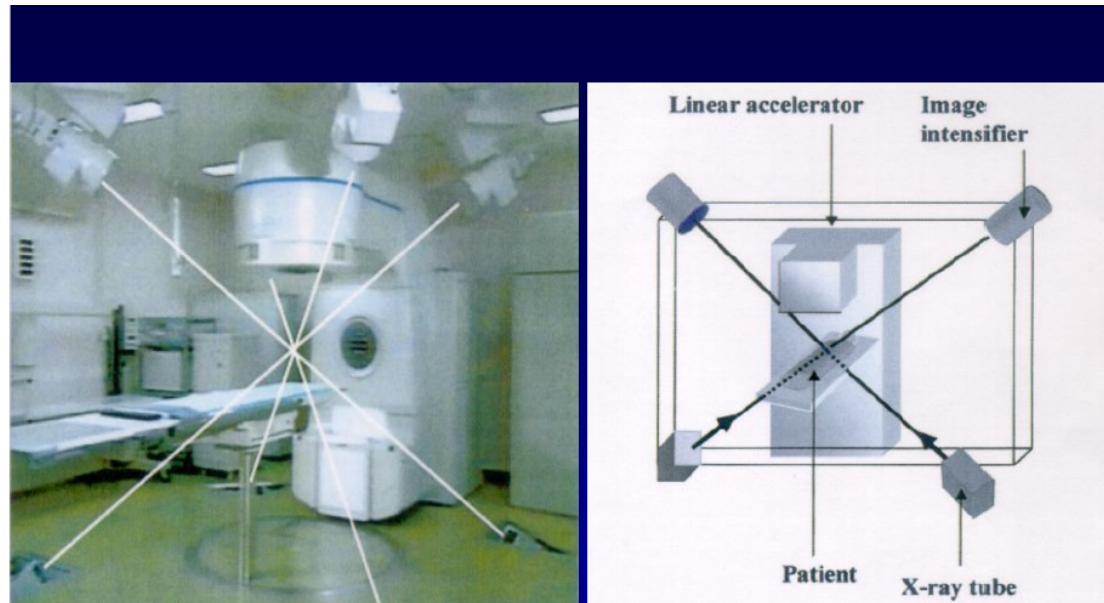
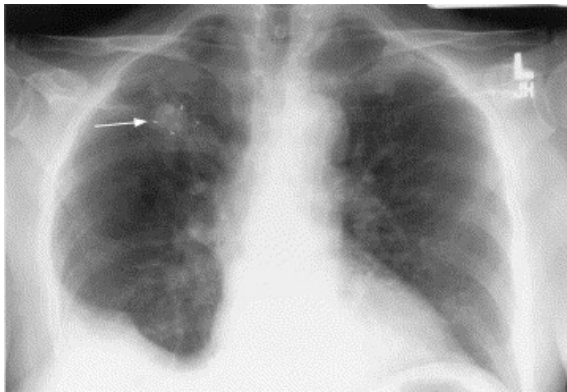


Ottimizzazione dei trattamenti

- Posizionamento di fiducials
- Controllo del respiro (4D)
- Cone-Beam CT

- Integrazione con la terapia sistemica

Posizionamento di fiducials

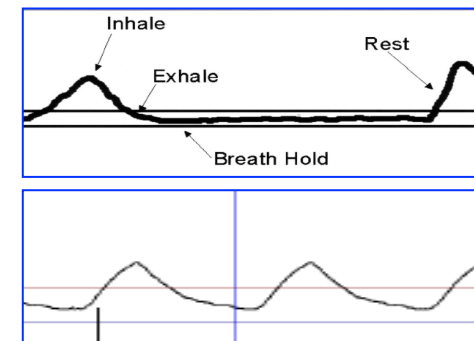


Determination of 3D coordinates of tumor markers by mean of fluoroscopic digitized images

La contornazione da 3D a 4D

Tecnologia per ridurre l'ITV

- Sistemi di compressione addominale
- Tecniche di respirazione controllata
- Sistemi di Gating respiratorio
- Acquisizione lenta TAC (4s)
- Fusione immagini TC/PET



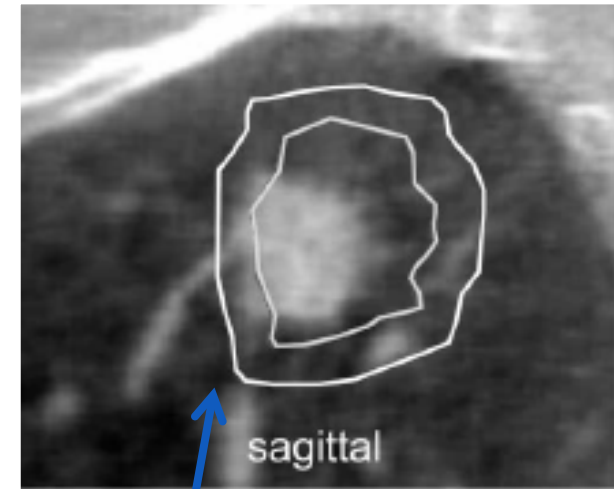
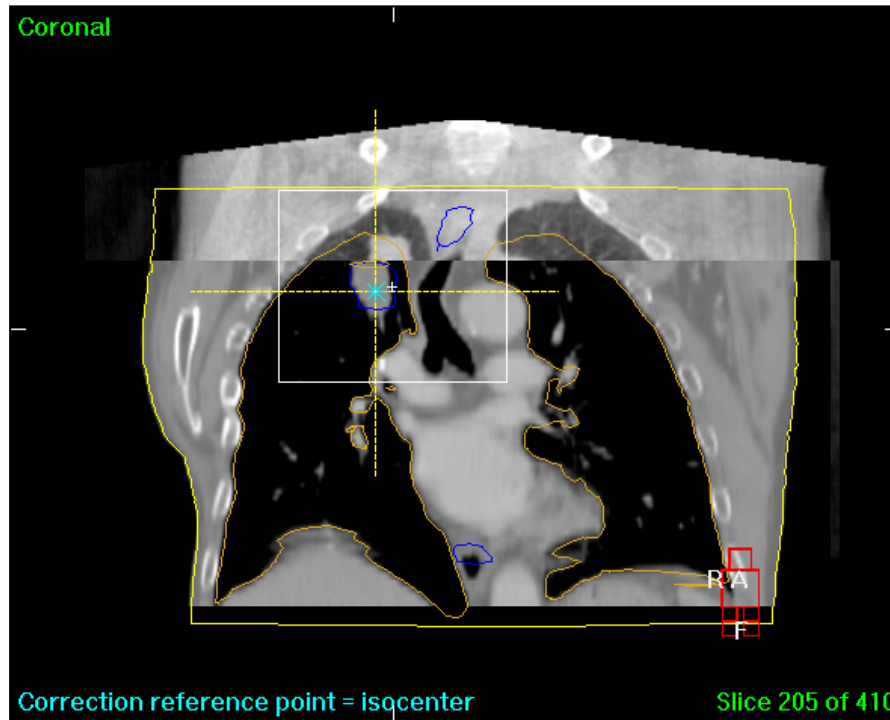
Cone Beam CT



- Una sola rotazione consente un'acquisizione volumetrica 3D completa
- 1 rotazione = 1 minuto

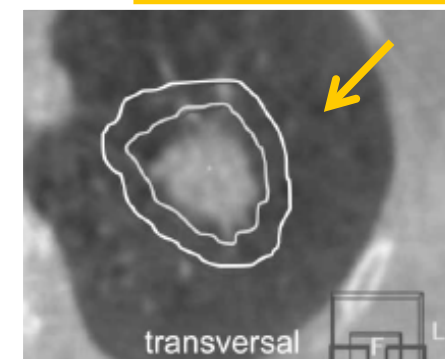
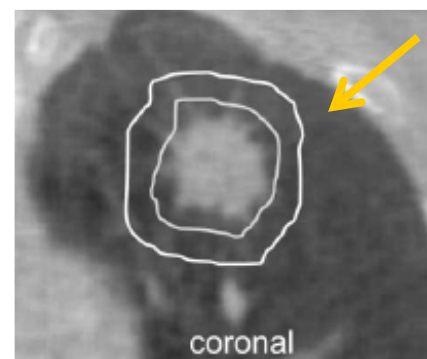
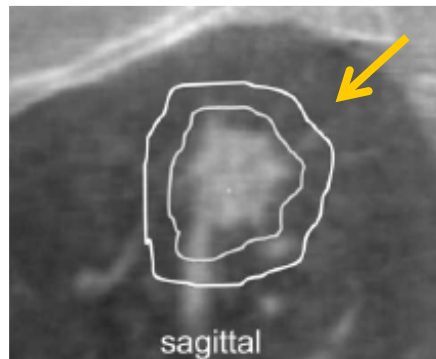


Cone beam CT

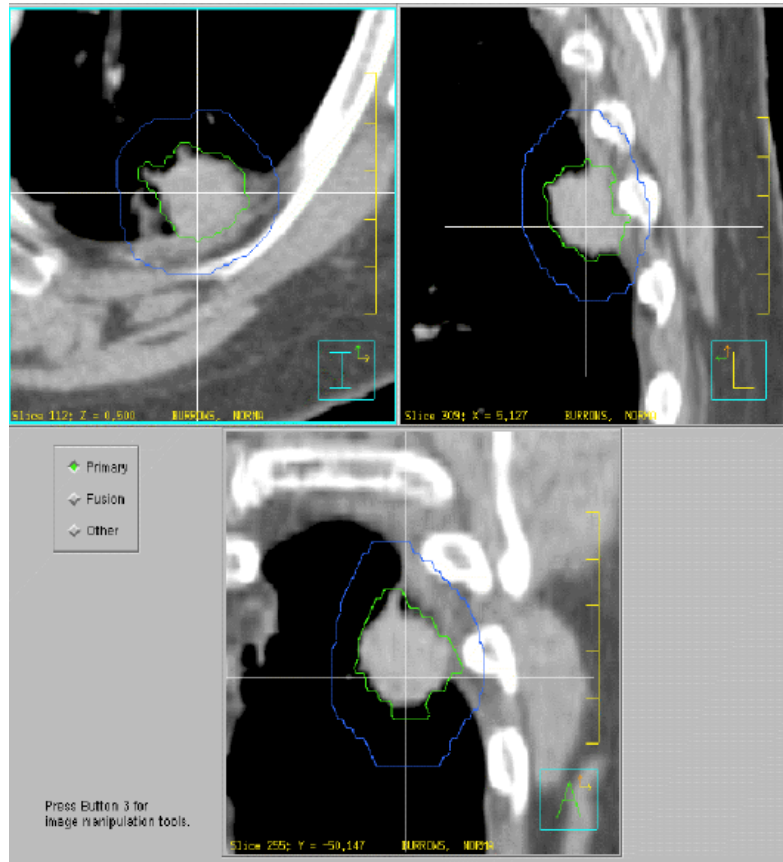


Pre-correzione

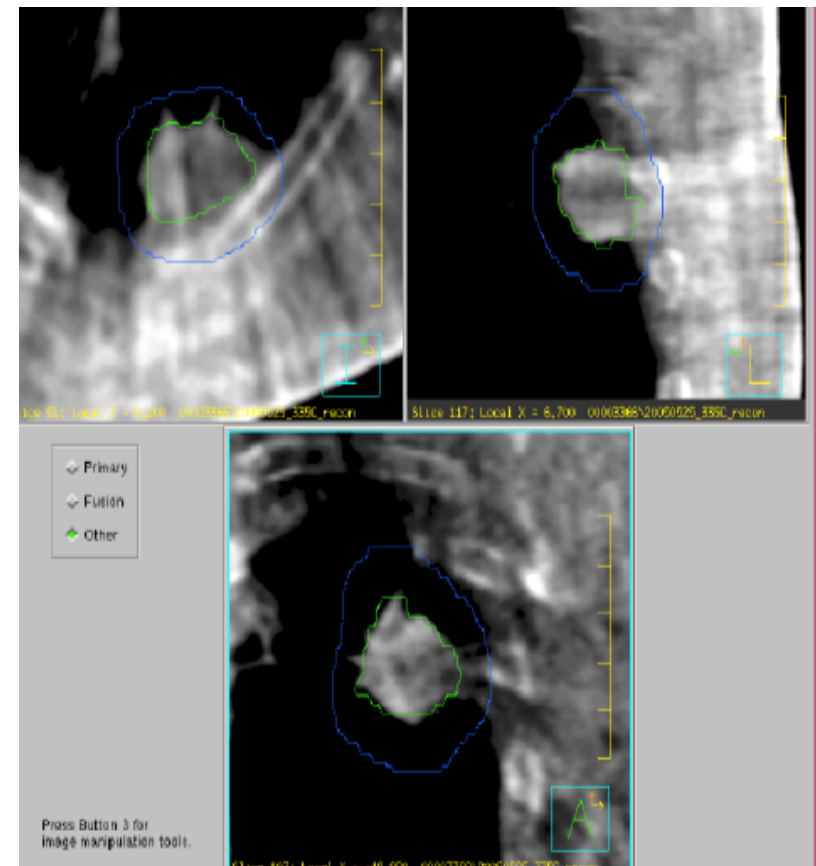
Post-correzione



Controllo on-line prima della RT



Planning / Reference Immage



Cone Beam CT Control Immage



Image

Slice Averaging
none

Display Mode
Localization on:

GoTo ..



Reference Preset

Cor Ref Point ..

Scan
 Alignment Clipbox
 Structures ..

Alignment

Automatic | Bone

Reset

Convert To Correction

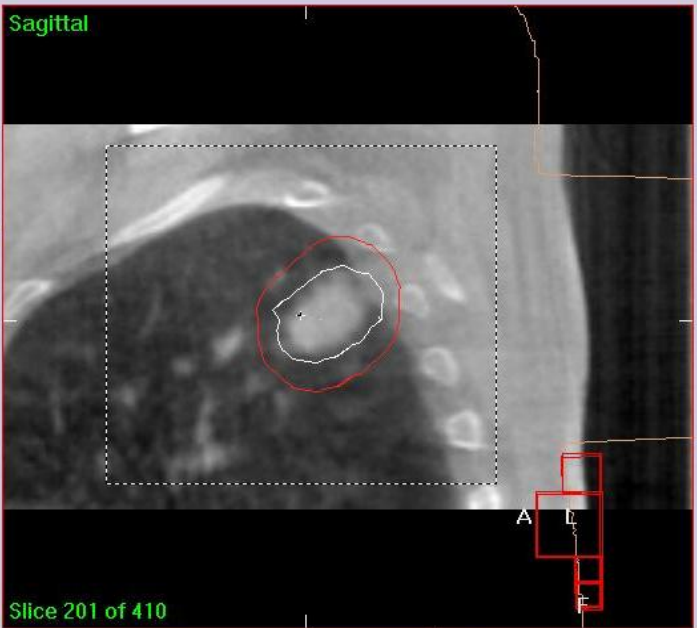
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Translation (cm)	Rotation (dg)
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Y <input type="text" value="0.00"/>	Y <input type="text" value="0.0"/>
Z <input type="text" value="0.00"/>	Z <input type="text" value="0.0"/>

Table Correction	(cm)
Lateral	-
Longitudinal	-
Vertical	-

Dismiss

Accept

File Help



Image

Slice Averaging
none

Display Mode
Localization only

GoTo ..



Reference Preset

Cor Ref Point..

Scan

Alignment Clipbox

Structures ..

Alignment

Automatic | Manual

Reset

Convert To Correction

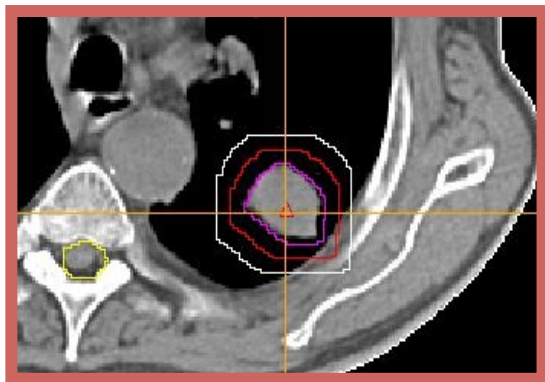
Position Error		Rotation (dg)	
Translation (cm)			
X	-0.75	X	359.6
Y	-0.05	Y	1.3
Z	0.88	Z	358.9

Table Correction		(cm)
Lateral		-
Longitudinal		-
Vertical		-

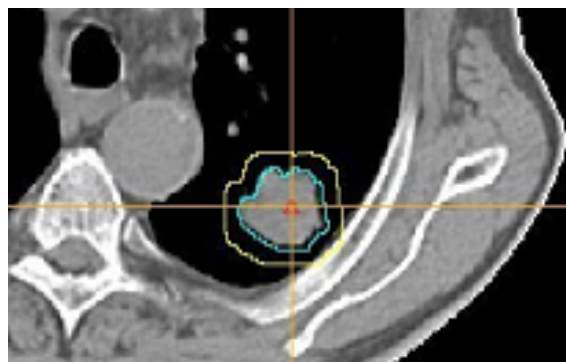
Dismiss

Accept

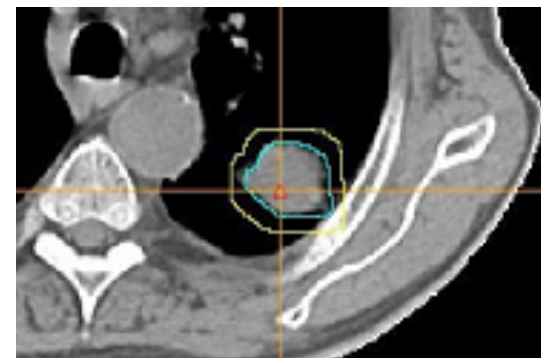
Variabilità del riposizionamento del CTV rispetto all' isocentro



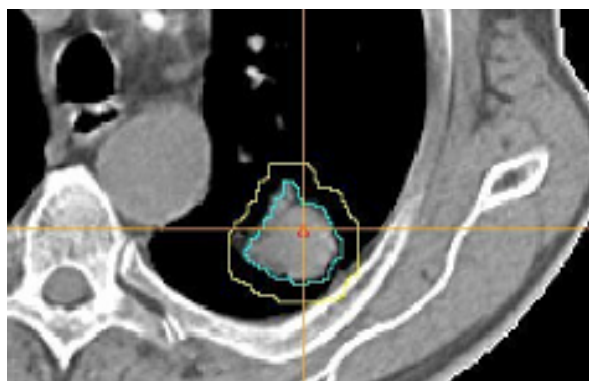
piano di trattamento



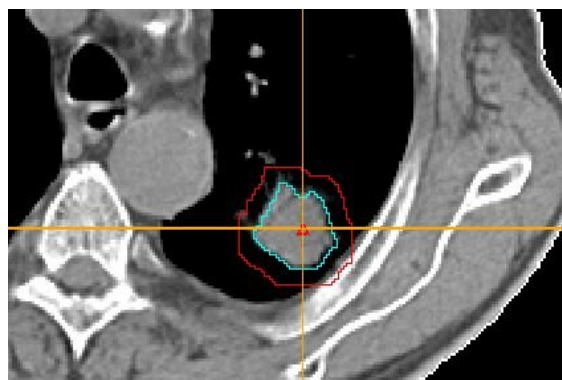
1° frazione



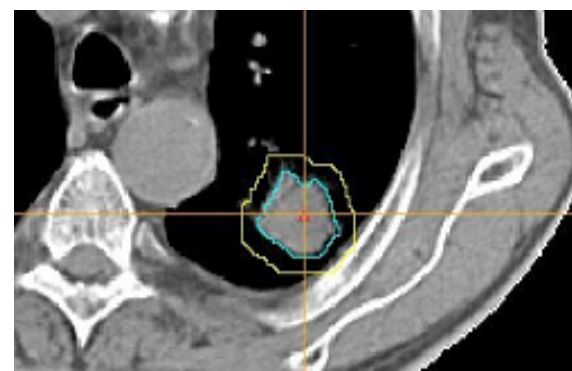
2° frazione



3° frazione



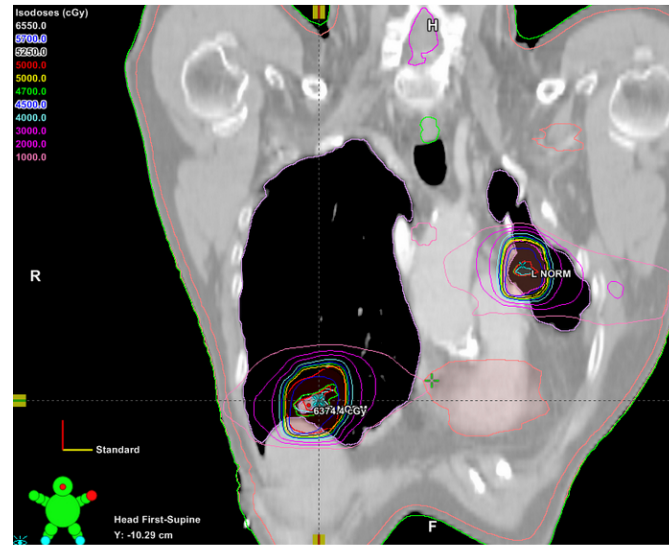
4° frazione



5° frazione

Tecniche di Radioterapia

- Stereotassi 3D/4D
- Cyberknife
- Tomotherapy
- Tecniche volumetriche (VMAT – Rapid Arc)



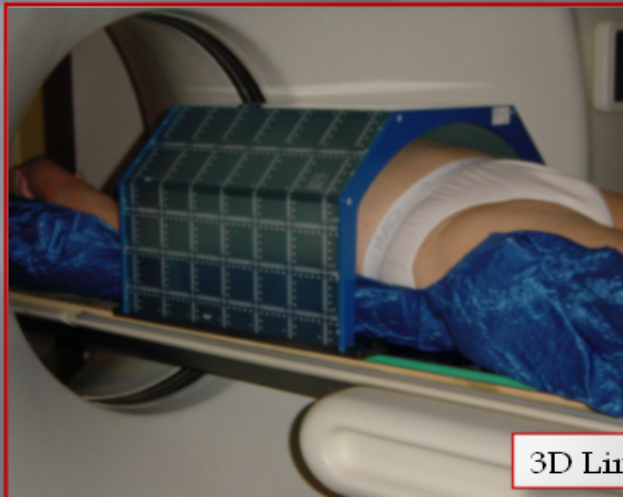
Stereotassi 3D: immobilizzazione e coordinate di riferimento



Medical Intelligence -Bodyfix



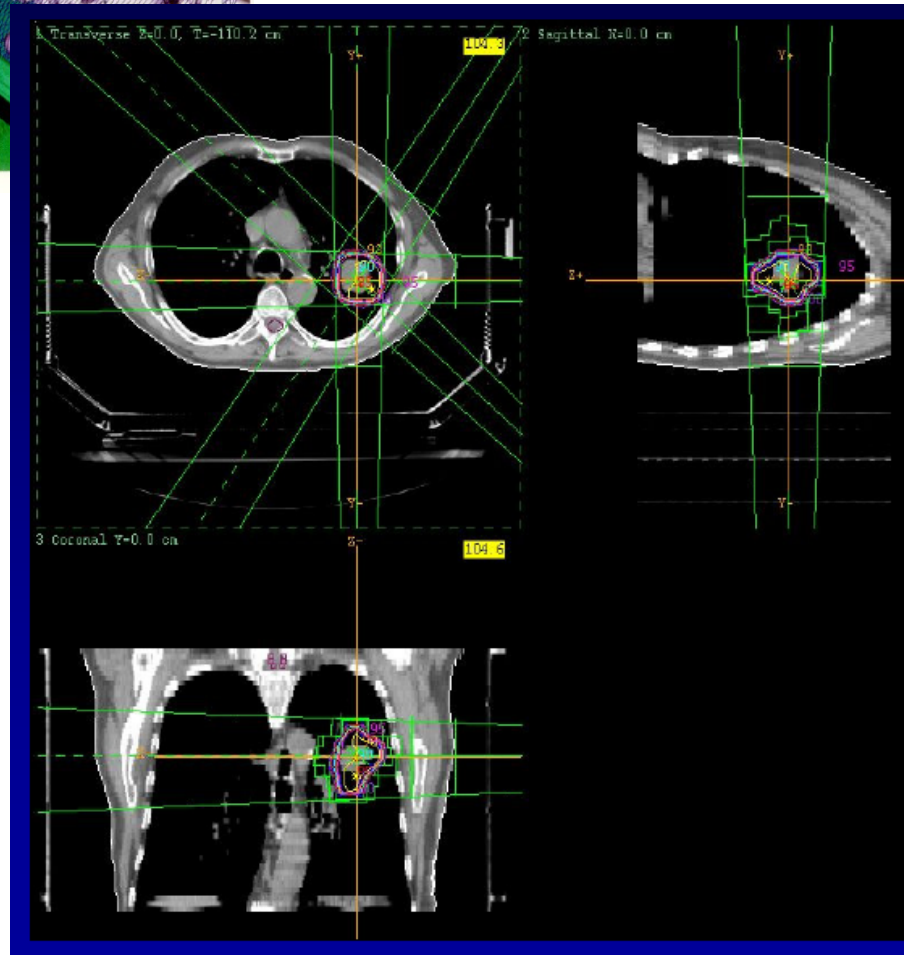
Elekta stereotactic Body Frame



3D Line Medical system



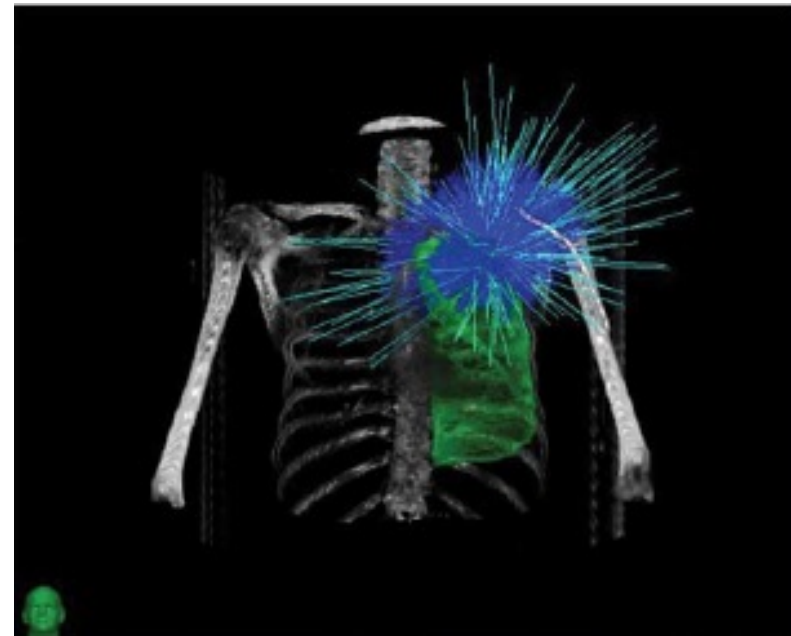
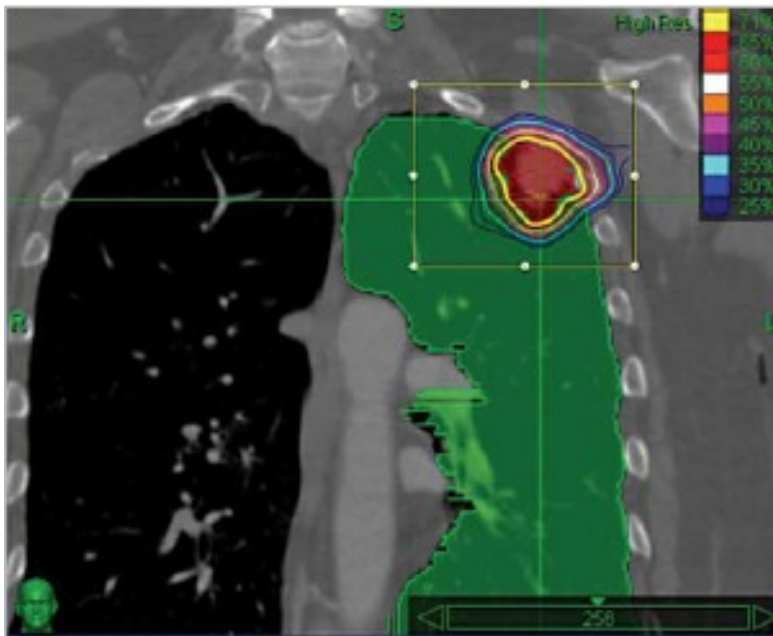
Planning



- ◆ Isocentro = punto di normalizzazione della dose
- ◆ Copertura completa del PTV con l'isodose 80% (Minima dose al PTV)
- ◆ Disomogeneità programmata della dose al PTV: 20-30% (110-80% della dose all'isocentro)

Cyberknife

- L'immagine coronale del piano di trattamento mostra il tumore, il parenchima polmonare e le linee isodosi
- L'immagine 3D mostra l'anatomia ossea, il polmone segmentato e la geometria dei fasci di irradiazione
- Prescrizione: 48 Gy alla 71% in 3 frazioni



courtesy of St. Joseph's Hospital, Phoenix, Arizona (USA)



CyberKnife with tumor tracking: an effective treatment for high-risk surgical patients with single peripheral lung metastases

James W. Snider¹, Eric K. Oermann¹, Viola Chen¹, Jennifer Rabin¹, Simeng Suy¹, Xia Yu¹, Saloomeh Vahdat², Sean P. Collins¹, Filip Banovac³, Eric Anderson⁴ and Brian T. Collins^{1*}

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³ Department of Radiology, Georgetown University Hospital, Washington, DC, USA
⁴ Division of Pulmonary, Critical Care and Sleep Medicine, Georgetown University Hospital, Washington, DC, USA

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Standard treatment for operable patients with single peripheral lung metastases is metastasectomy. We report mature CyberKnife outcomes for high-risk surgical patients with biopsy proven single peripheral lung metastases. Twenty-four patients (median age 73 years) with a mean maximum tumor diameter of 2.5 cm (range, 0.8–4.5 cm) were treated over a 6-year period extending from September 2004 to September 2010 and followed for a minimum of 1 year or until death. A mean dose of 52 Gy (range, 45–60 Gy) was delivered to the prescription isodose line in three fractions over a 3–11 day period (mean, 7 days). At a median follow-up of 20 months, the 2-year Kaplan–Meier local control and overall survival rates were 87 and 50%, respectively. CyberKnife with fiducial tracking is an effective treatment for high-risk surgical patients with single small peripheral lung metastases. Trials comparing CyberKnife with metastasectomy for operable patients are necessary to confirm equivalence.



24 pazienti
con fiducials

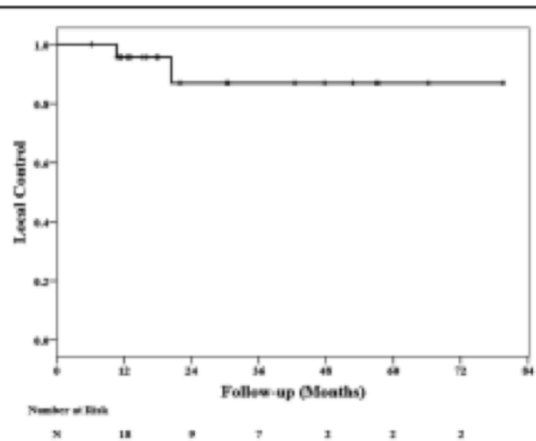
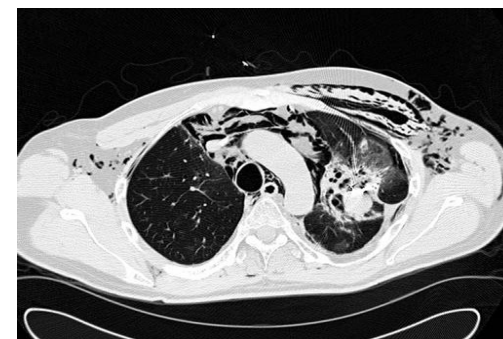


FIGURE 1 | Kaplan-Meier local control plot.

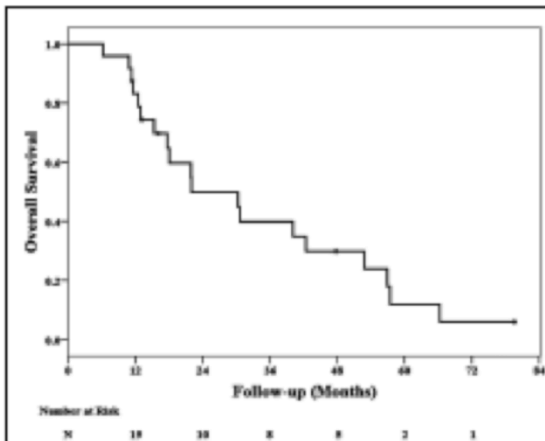


FIGURE 2 | Kaplan-Meier overall survival plot.

Table 1 | Critical central structure radiation point dose limits.

Adjacent structure	Maximum dose limit (total for 3 fractions; Gy)
Spinal cord	18
Esophagus	27
Heart	30
Main bronchus	30
Trachea	30
Great vessels	40

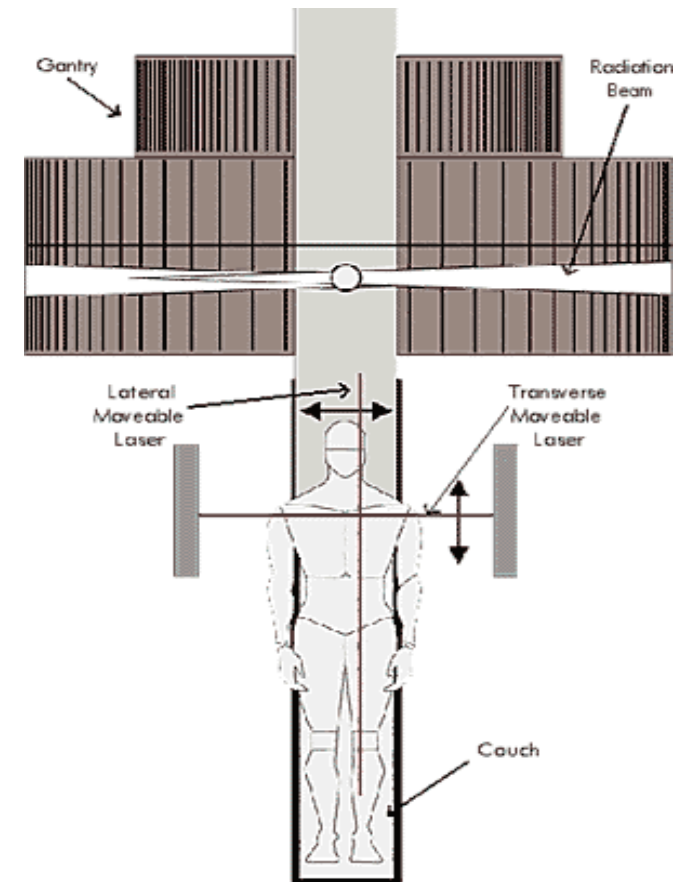
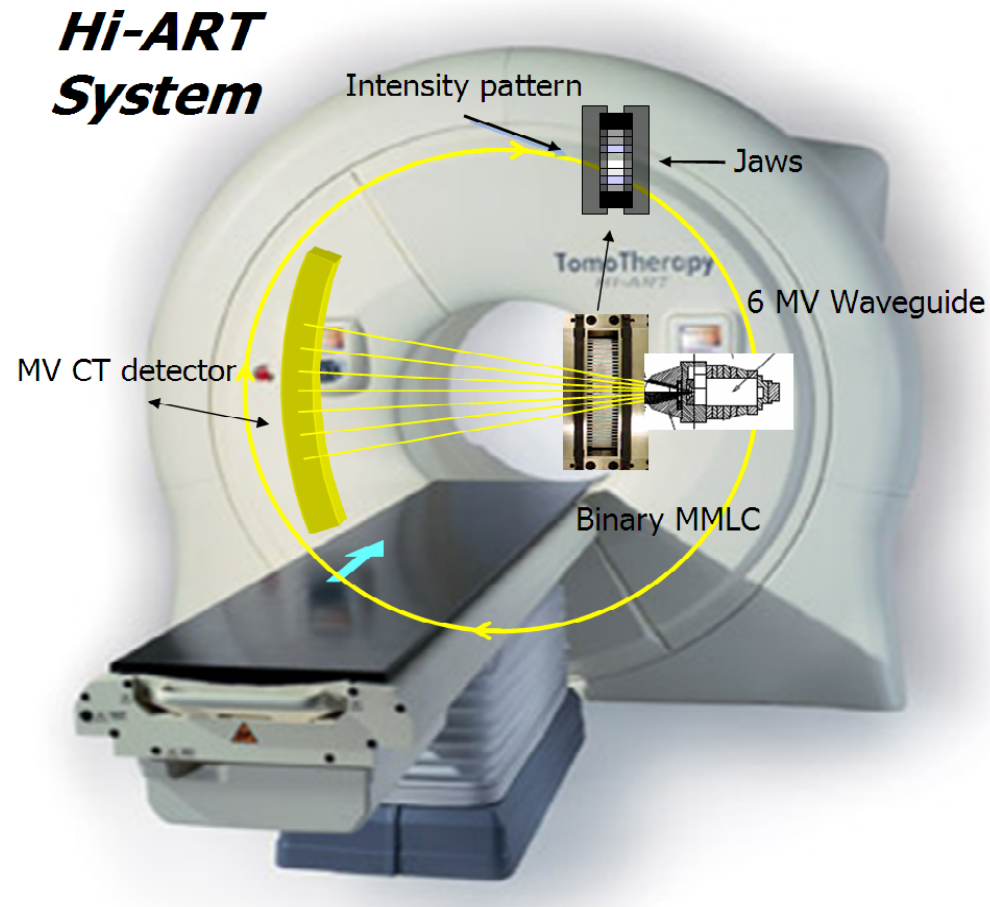
Sistema Robotico CyberKnife

gating respiratorio

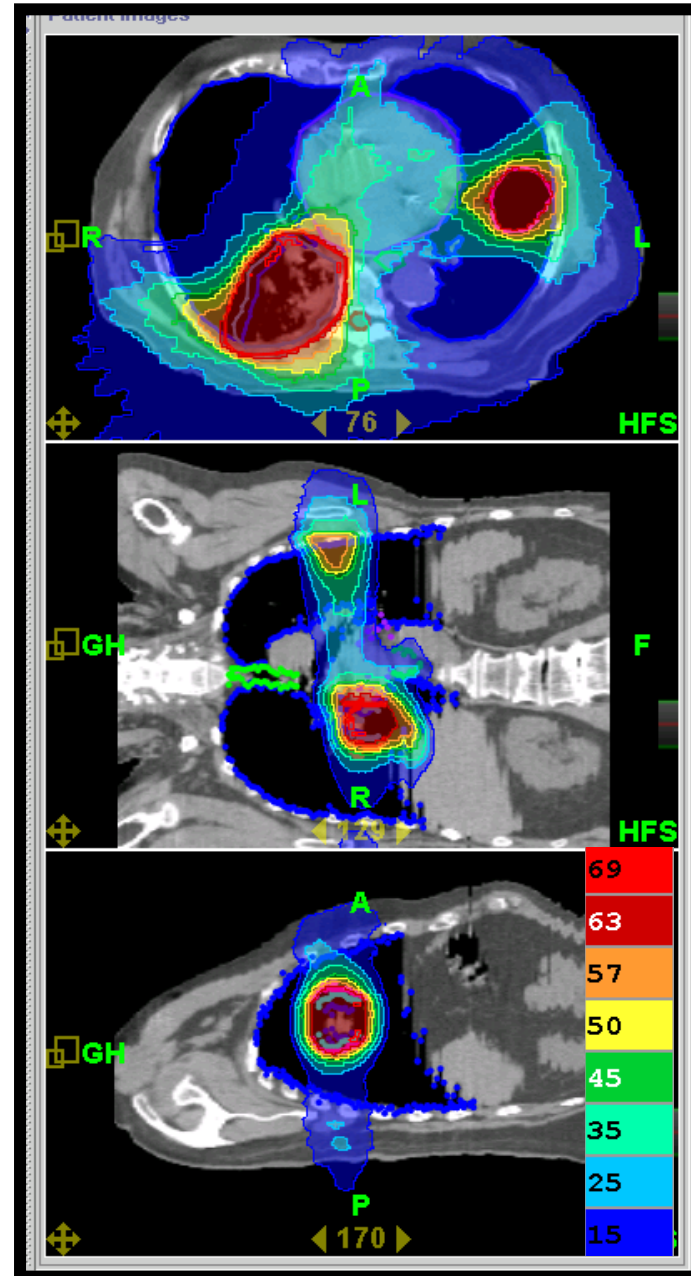
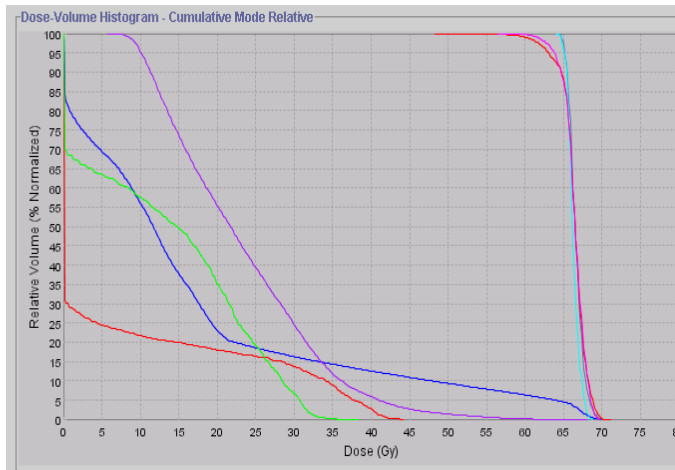
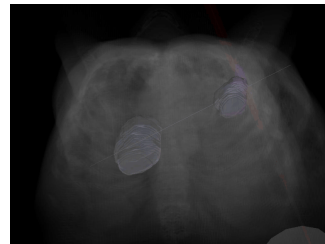
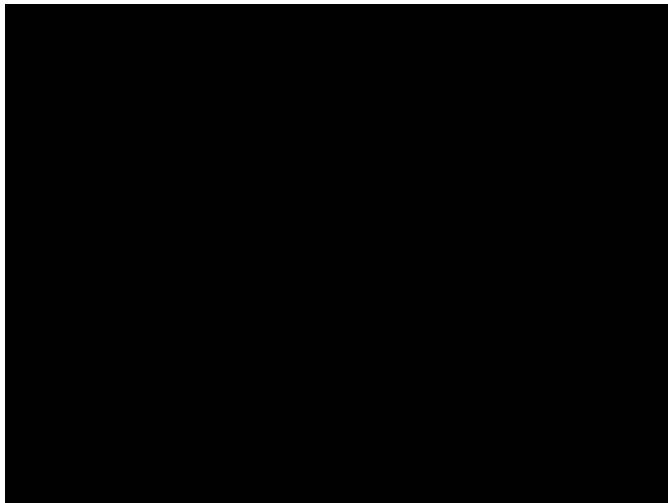
- Synchrony™ è il sistema che permette di sincronizzare il movimento del Robot con il movimento della lesione dovuto al respiro
- Il paziente respira liberamente mentre il Robot eroga il fascio di trattamento
- L'accuratezza radiochirurgica è mantenuta, i tessuti sani sono risparmiati e i margini del PTV sono di pochi millimetri



Tomotherapy



Tomotherapy



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FEASIBILITY OF HELICAL TOMOTHERAPY IN STEREOTACTIC BODY RADIATION THERAPY FOR CENTRALLY LOCATED EARLY STAGE NON-SMALL-CELL LUNG CANCER OR LUNG METASTASES

Table 2. Dose constraints for the prescription dose of 70 Gy delivered in 10 fractions

Critical structures	Maximum tolerated dose (Gy)
Spinal cord	28
Esophagus	44
Major airway	49
Heart	49
Brachial plexus	38.5
Major vessels	49
Total lung*	
V ₂₀	20
Mean lung dose	9.5

* Total lung volume = total volume of both lungs minus that of the GTV. V₂₀ is the % of the volume receiving 20 Gy.

Table 5. Maximum dose to the organs at risk (including organs immediately adjacent to the tumor)

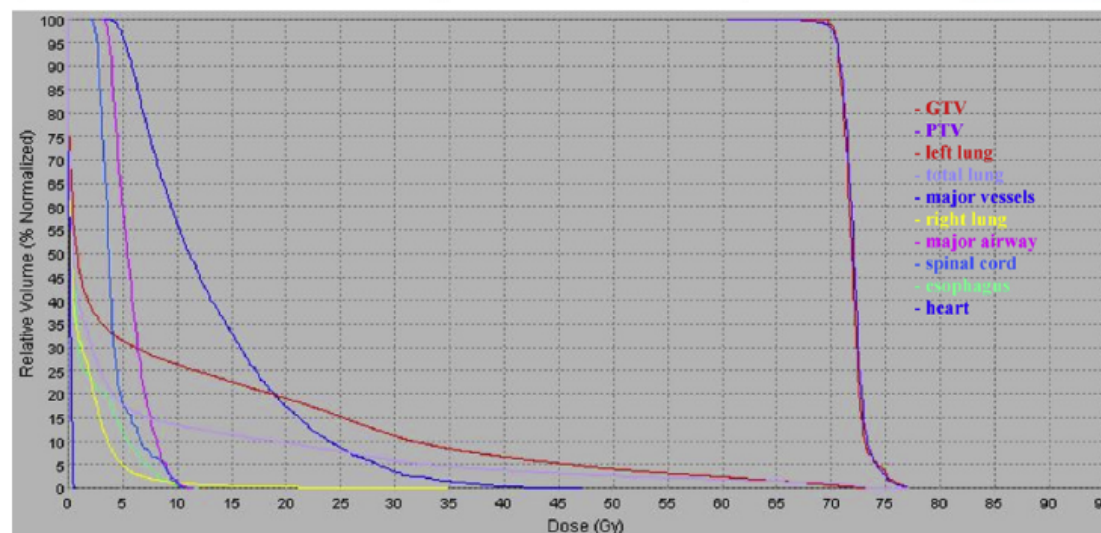
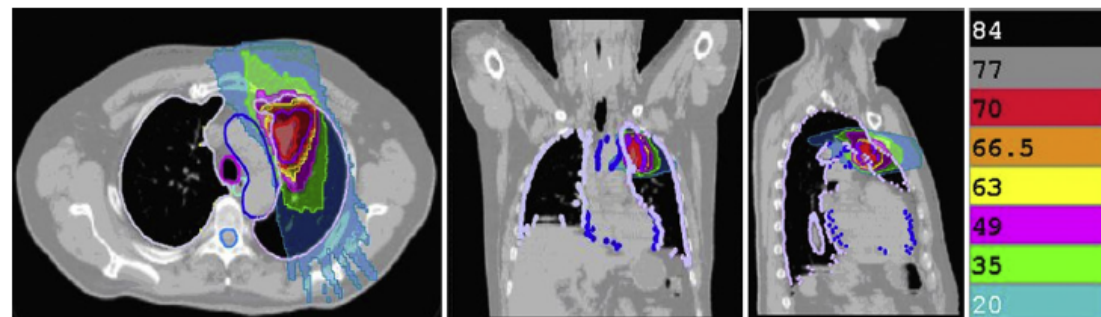
Organs at risk	Maximum dose received
Spinal cord (SD)	18.20 (8.05)
Esophagus (SD)	12.56 (5.27)
Heart (SD)	18.89 (22.49)
Major airway (SD)	24.27 (13.21)
Major vessels (SD)	43.26 (5.09)

Table 4. Dose to the normal lung tissue in tomotherapy SBRT plans

	Total lung	Ipsilateral lung	Contralateral lung
MLD (SD)	7.15 (1.44)	12.78 (2.53)	1.62 (0.46)
V ₅ (SD)	21.81 (2.11)	40.11 (5.76)	5.87 (3.69)
V ₁₀ (SD)	16.21 (2.97)	34.08 (5.10)	0.73 (0.60)
V ₂₀ (SD)	11.93 (3.24)	25.06 (5.78)	0.06 (0.10)

Abbreviations: MLD = mean lung dose; V₅, V₁₀, V₂₀ = % volume receiving 5 Gy, 10 Gy, and 20 Gy, respectively; SD = standard deviation.

Chi A, IJROBP 2011



VMAT – Rapid Arc

- IMRT con Tecnica Volumetrica Rotazionale
- Tempo di trattamento breve: ~5'





Volume Modulated Arc Therapy (VMAT) for pulmonary Stereotactic Body Radiotherapy (SBRT) in patients with lesions in close approximation to the chest wall

Linda Ding¹, Yuan-Chyuan Lo¹, Sidney Kadish¹, David Goff¹, Richard S. Pieters¹, Geoffrey Graeber², Karl Uy², Syed Quadri², Richard Moser³, Kevin Martin^{4,5}, John Day⁶ and Thomas J. FitzGerald^{1*}

60 Gy in 5 frazioni

VMAT Technology for Pulmonary SBRT in Patients with Lesions in Close Approximation to the Chest Wall

Table 2 | V30 for chest wall and ribs was reduced for all 10 patients from original planning technique.

Patient	Chest wall volume receive >30 Gy (%)	Ribs receive >30 Gy (%)	V20 lung dose ()
1	-65.5	-59.2	-2.4
2	-60.5	-91.1	-32.0
3	-32.2	-11.1	-6.5
4	-93.3	-51.4	12.6
5	-55.0	-47.9	-18.3
6	-57.0	-100.0	-54.1
7	-100.0	-69.1	-26.3
8	-62.1	-37.1	-3.9
9	-54.1	-40.9	-16.7
10	-55.6	-100.0	-52.0

V20 lung dose decreased for 9 of the 10 patients. The data is presented as percent decrease in volume treated using VMAT technology.

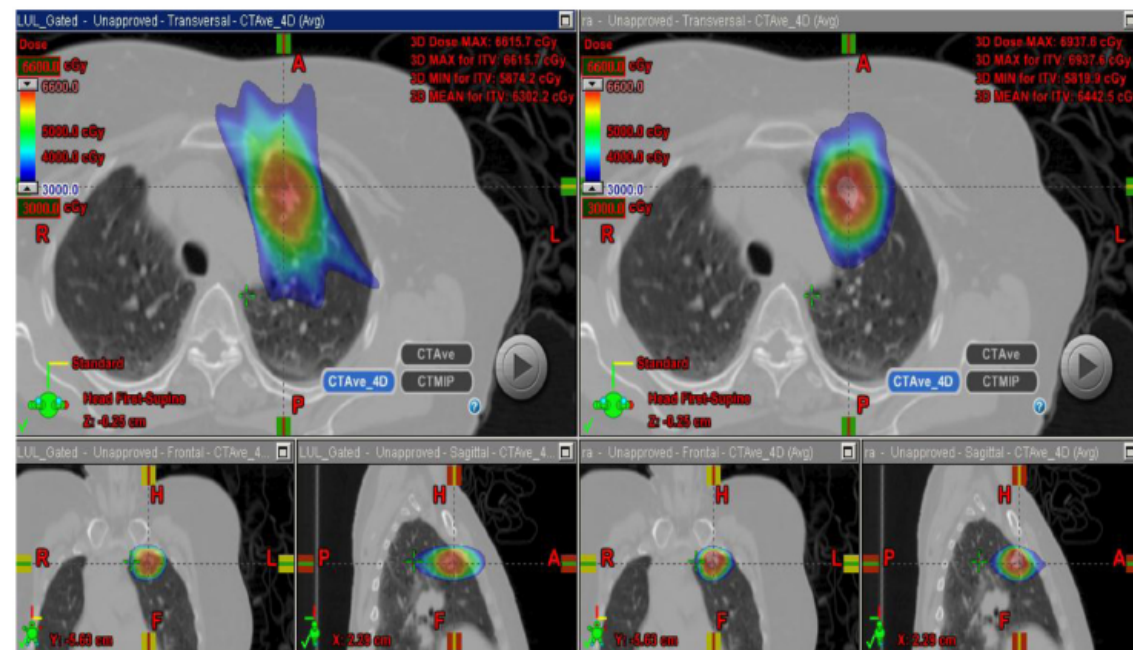


FIGURE 1 | Demonstrates improvement in dosimetry in a lesion in the anterior segment of the left upper lobe with the static field plan on the left and the VMAT plan on the right.

Risultati e Complicanze

Table 1. Outcomes of stereotactic body radiation therapy for lung metastases from selected trials

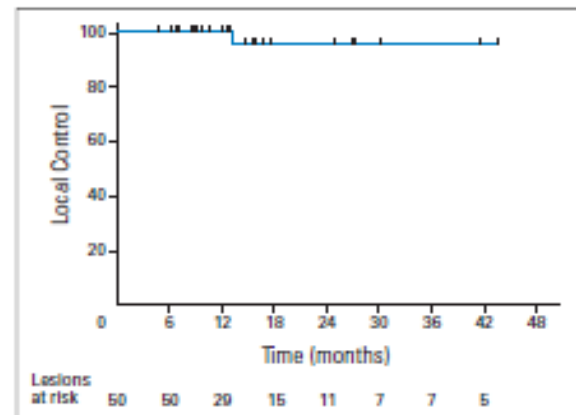
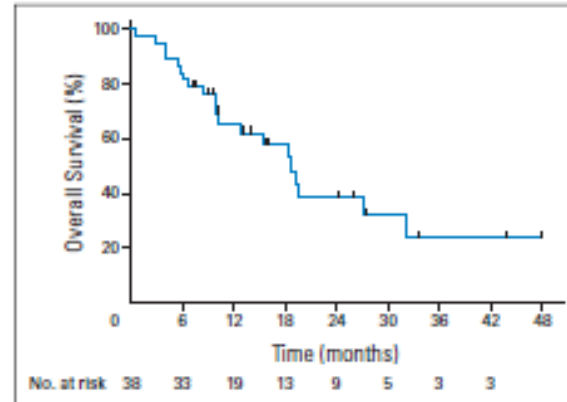
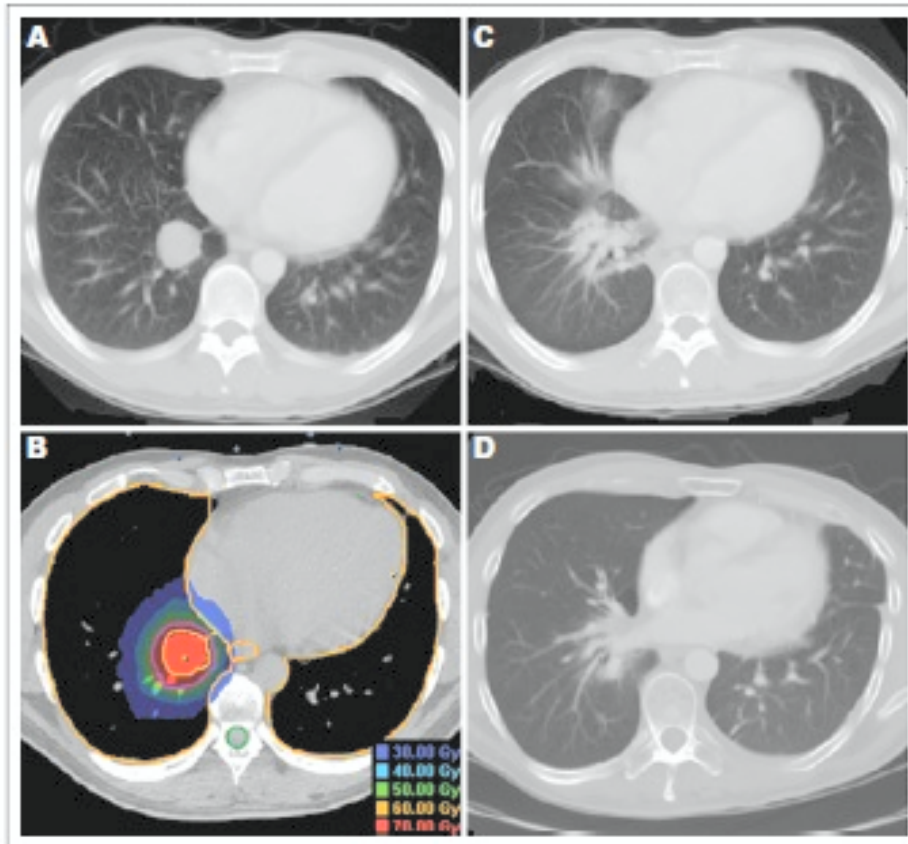
Study	n of patients	Median dose/n of fractions	Median (range) follow-up, mos	Local control rate	Overall survival	Toxicity
Onimaru et al. [5]	45	48 Gy/8; 60 Gy/8	18 (2–44)	3-yr, 69.6% for 48 Gy, 100% for 60 Gy	2-yr, 47.1%	Grade 5, 1 (2.2%)
Wulf et al. [32]	27	30 Gy/3; 36 Gy/3	13–17	2-yr, 71%	1-yr, 48% 2-yr, 21%	Grade 3, 1 (3.7%) Grade 5, 1 (3.7%)
Yoon et al. [71]	53	30 Gy/3; 40 Gy/4; 48 Gy/4	14 (4–56)	70% for 30 Gy, 77% for 40 Gy, 100% for 48 Gy	1-yr, 89%; 2-yr, 51%	Grade \geq 2, 0%
Okunieff et al. [18]	50	50 Gy/10; 48 Gy/6; 57 Gy/3	18.7 (3.7–60.9)	3-yr, 91%	2-yr, 50%	Grade 2, 6.1% Grade 3, 2%
Norihisa et al. [6]	34	48 Gy/4; 60 Gy/5	27 (10–80)	2-yr, 90%	2-yr, 84%	Grade 2, 4 (12%) Grade 3, 1 (3%)
Brown et al. [72]	35	5 Gy/1 to 60 Gy/4	18 (2–41)	Crude, 77%	2-yr, 72.5%	Grade 3–4, 1 (2.8%)
Rusthoven et al. [14]	38	60 Gy/3	15.4 (6–48)	2-yr, 96%	2-yr, 39%	No grade 4 Grade 3, 3 (8%)
Ricardi et al. [17]	61	45 Gy/3; 26 Gy/1	20.4 (3–77)	2-yr, 89%	2-yr, 66.5	Grade 3, 1 (1.6%)

Alongi F et al, *The Oncologist* 2012, 17:1100-1107.

Risultati e Complicanze

- Controllo locale: 70 - 100% ad un anno
- Sopravvivenza: 39 – 84% a due anni
 - se M1 solitaria
 - 70% a 2 anni
 - 36% a 5 anni
- Sopravvivenza media: 11,3 – 42,8 mesi
- Tossicità ≥ 3 : 2,6 % RT frazione unica
 - 4% RT ipofrazionata
 - maggiore per localizzazioni centrali

Multi-Institutional Phase I/II Trial of Stereotactic Body Radiation Therapy for Lung Metastases



38 pazienti con 1→3 metastasi polmonari
 63 lesioni < 70 mm
 48 → 60 Gy in tre frazioni

Tossicità G3 8%:
 2 casi: parete toracica e costa
 1 caso: polmonite

Organi a rischio e limiti di dose

- Polmone $V_{12} < 20\%$
- Midollo spinale
15Gy (3 fraz.)
13,5 Gy (5 fraz.)
- Esofago $< 4 \text{ Gy x frazione}$
- Cuore $V_{15} < 10\%$
- Parete toracica e coste: 40 Gy max a 5 cc
 $\leq 50\text{Gy}$
- Bronco $< 30\text{Gy}$

Pathological vertebral fracture after stereotactic body radiation therapy for lung metastases. Case report and literature review.

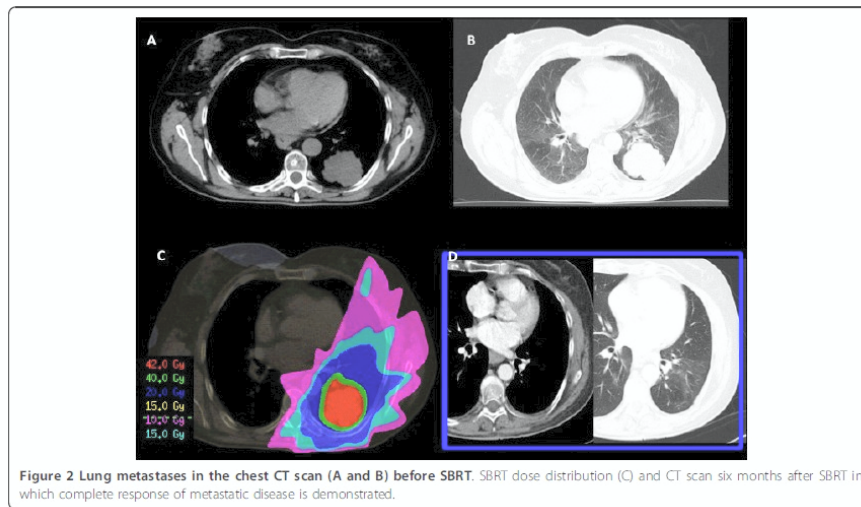
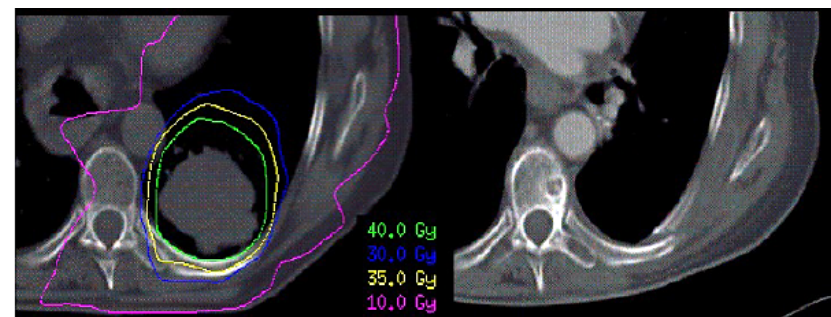
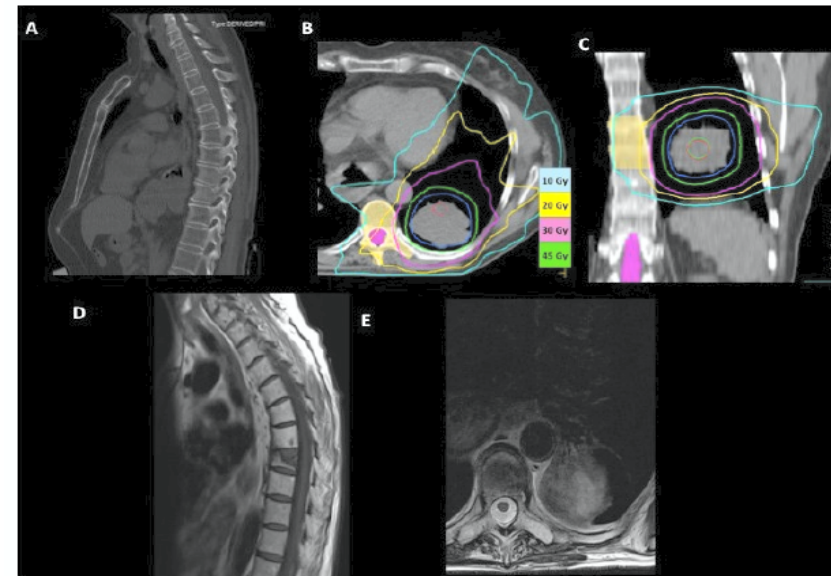


Figure 2 Lung metastases in the chest CT scan (A and B) before SBRT. SBRT dose distribution (C) and CT scan six months after SBRT in which complete response of metastatic disease is demonstrated.

Rodríguez-Ruiz *et al. Radiation Oncology* 2012, **7**:50



PRINCIPLES OF RADIATION THERAPY (6 of 9)

Table 2. Commonly Used Doses for SABR

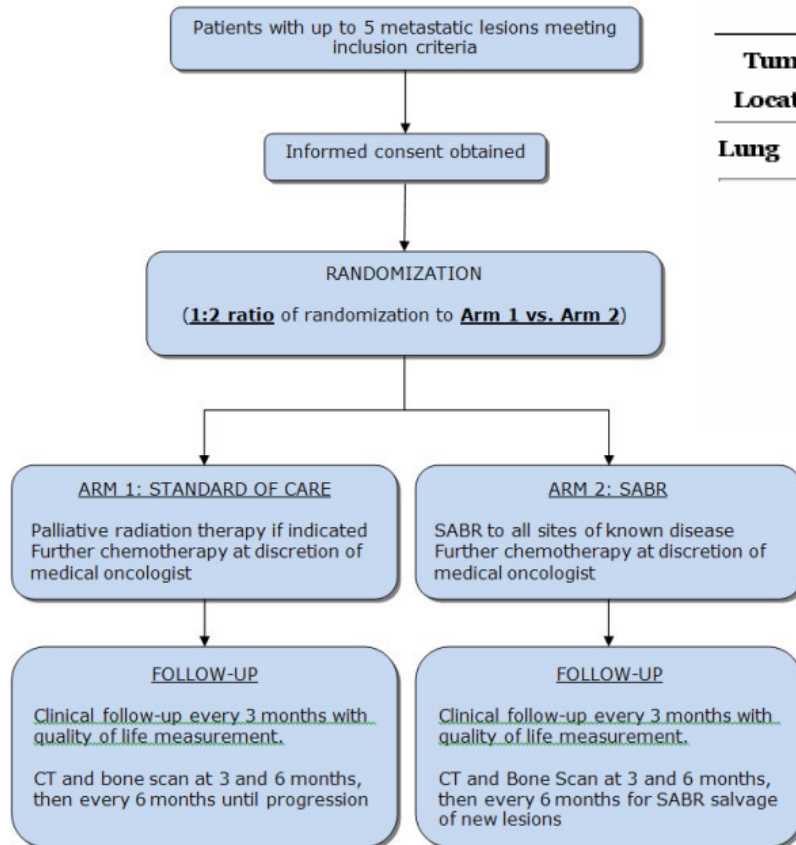
Total Dose	# Fractions	Example Indications
25-34 Gy	1	Peripheral, small (<2 cm) tumors, esp. >1 cm from chest wall
45-60 Gy	3	Peripheral tumors and >1 cm from chest wall
48-50 Gy	4	Central or peripheral tumors <4-5 cm, esp. <1 cm from chest wall
50-55 Gy	5	Central or peripheral tumors, esp. <1 cm from chest wall
60-70 Gy	8-10	Central tumors

Table 3. Maximum Dose Constraints for SABR*

OAR/Regimen	1 Fraction	3 Fractions	4 Fractions	5 Fractions
Spinal Cord	14 Gy	18 Gy (6 Gy/fx)	26 Gy (6.5 Gy/fx)	30 Gy (6 Gy/fx)
Esophagus	15.4 Gy	30 Gy (10 Gy/fx)	30 Gy (7.5 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Brachial Plexus	17.5 Gy	21 Gy (7 Gy/fx)	27.2 Gy (6.8 Gy/fx)	30 Gy (6 Gy/fx)
Heart/ Pericardium	22 Gy	30 Gy (10 Gy/fx)	34 Gy (8.5 Gy/fx)	35 Gy (7 Gy/fx)
Great Vessels	37 Gy	39 Gy (13 Gy/fx)	49 Gy (12.25 Gy/fx)	55 Gy (11 Gy/fx)
Trachea & Proximal Bronchi	20.2 Gy	30 Gy (10 Gy/fx)	34.8 Gy (8.7 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Rib	30 Gy	30 Gy (10 Gy/fx)	30 Gy (7.5 Gy/fx)	32.5 Gy (6.5 Gy/fx)
Skin	26 Gy	30 Gy (10 Gy/fx)	36 Gy (9 Gy/fx)	40 Gy (8 Gy/fx)
Stomach	12.4 Gy	27 Gy (9 Gy/fx)	30 Gy (7.5 Gy/fx)	35 Gy (7 Gy/fx)

*Based on constraints used in recent and ongoing RTOG SABR trials (RTOG 0618, 0813, & 0915).

Stereotactic ablative radiotherapy for comprehensive treatment of oligometastatic tumors (SABR-COMET): Study protocol for a randomized phase II trial



Dose and fractionations by site

Tumor Location	Description	Total Dose (Gy)	Number fraction
Lung	Tumors 3 cm or less surrounded by lung parenchyma	54	3
	Abutting chest wall or >3 cm	55	5
	Within 2 cm of mediastinum or brachial plexus	60	8*

Trattamenti alternativi

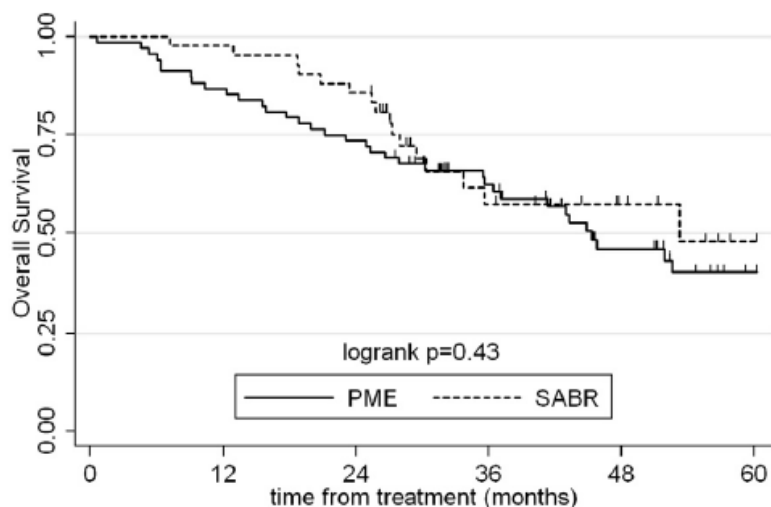
■ Chirurgia:

- da preferire quando è necessario avere una conferma istologica
- sopravvivenza a 5 anni: 30 → 65%
- vantaggio incerto

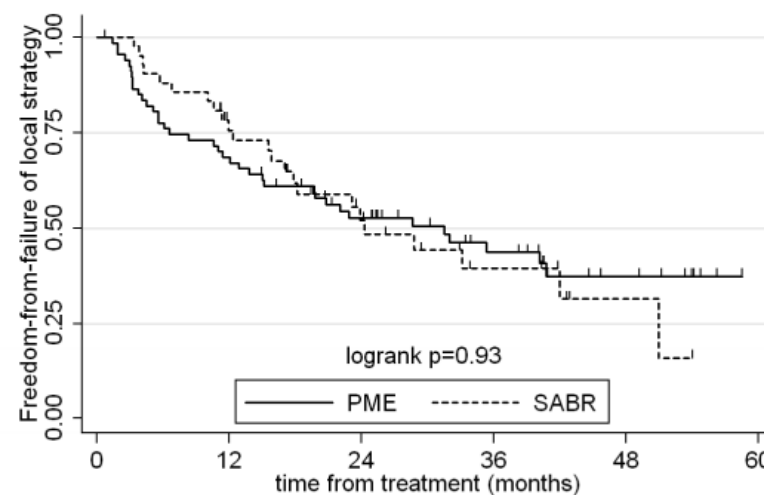
- [1] Pfannschmidt J, Dienemann H, Hoffmann H. Surgical resection of pulmonary metastases from colorectal cancer: a systematic review of published series. *Ann Thorac Surg* 2007;84:324–38.
- [2] Timmerman R, Bizakis C, Pass H, et al. Local surgical, ablative, and radiation treatment of metastases. *CA Cancer J Clin* 2009;59:145–70.
- [3] Pastorino U, Buyse M, Friedel G, et al. Long-term results of lung metastasectomy: prognostic analyses based on 5206 cases. *The International Registry of Lung Metastases. J Thorac Cardiovasc Surg* 1997;113:37–49.
- [4] Treasure T. Pulmonary metastasectomy: a common practice based on weak evidence. *Ann R Coll Surg Engl* 2007;89:744–8.
- [5] Hornbech K, Ravn J, Steinbruchel DA. Current status of pulmonary metastasectomy. *Eur J Cardiothorac Surg* 2011;39:955–62.

Pulmonary oligometastases: Metastasectomy or stereotactic ablative radiotherapy? ☆

Joachim Widder^{a,*}, Theo J. Klinkenberg^b, Jan F. Ubbels^a, Erwin M. Wiegman^a, Harry J.M. Groen^c, Johannes A. Langendijk^a



Number at risk		0	12	24	36	48	60
PME	68	59	50	35	20	9	
SABR	42	41	36	14	8	2	



Number at risk		0	12	24	36	48	60
PME	68	46	31	18	8	0	
SABR	42	28	15	7	2	0	

Table 1A: Univariable Cox regression analysis for overall survival

Variable	HR (95 % CI)	p-value
SABR versus PME	0.79 (0.43–1.42)	0.427
Age (per year)	1.00 (0.98–1.03)	0.865
Sex (female versus male)	0.64 (0.36–1.14)	0.130
Colorectal primary (versus other)	0.86 (0.49–1.51)	0.605
Metastases-free-interval (per month)	0.99 (0.98–1.01)	0.187
Number of lesions (per lesion)	1.21 (0.90–1.62)	0.198
Size of largest lesion (per centimetre)	0.80 (0.60–1.08)	0.140
Previous chemotherapy (versus no chemotherapy)	1.04 (0.54–2.09)	0.895

PME: pulmonary metastasectomy

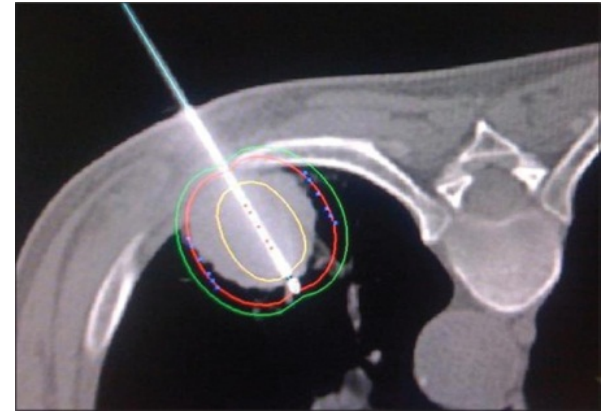
SABR: stereotactic ablative radiotherapy for pulmonary metastases

60 Gy in 3, 5, 8 frazioni per neoplasie centrali, a parete, adiacenti grossi bronchi o vasi

Trattamenti alternativi

■ Radiofrequenza:

- frazione unica
- Indicata per metastasi di max 30-35 mm periferiche ma non dell' apice o posizionate in prossimità della scapola
- controllo locale 88%
- PNX 28%; pleurite 14%, dolore 14%



Is radiofrequency ablation more effective than stereotactic ablative radiotherapy in patients with early stage medically inoperable non-small cell lung cancer?

Haris Bilal^a, Sarah Mahmood^b, Bala Rajashanker^c and Rajesh Shah^{a,*}

16 lavori selezionati su 219 pubblicati

tipo	Sopravvivenza %			Progressione locale %	PNX %	Fatigue %	Polmonite %
	1 anno	3 anni	5 anni				
RFA	68 - 95	36 - 87	20 - 27	24 - 43	19 - 63		
SABR	81 - 86	43 - 56	47	3 - 14		31 - 33	2 - 12

RFA : radiofrequenza

SABR : radioterapia stereotassica ablativa



Stereotactic radiosurgery and stereotactic body radiation therapy cost-effectiveness results

Akash Bijlani¹, Giovanni Aguzzi², David W. Schaal¹ and Pantaleo Romanelli^{2*}

Table 2 | Lung publication characteristics, estimated costs, and effectiveness.

Reference	Country	Type of study	Procedures compared	Perspective	Cost types	Local currency	Procedures cost per patient	Effectiveness	ICER/ICUR/Cost analysis results
Lanni et al. (2011)	USA	Cost-effectiveness	SBRT 3DCRT IMRT	Service provider	Direct	USD	SBRT: \$52,471 3DCRT: \$55,705 IMRT: \$136,570	SBRT 36-month overall survival: 71% 3DCRT 36-month overall survival: 42% IMRT 36-month overall survival: na	SBRT dominates
Shen et al. (2010)	USA	Cost-utility	SBRT 3DCRT RFA	Service provider	Direct	USD	SBRT: \$91,130 3DCRT: \$48,842 RFA: \$44,648	SBRT: 1.91 QALY 3DCRT: 1.53 QALY RFA: 1.45 QALY	SBRT vs. 3DCRT: \$4,000/QALY SBRT vs. RFA: \$14,100/QALY
Puri et al. (2012)	USA	Cost-effectiveness	SBRT Surgery	Healthcare payer	Direct	USD	SBRT: \$14,153 Surgery: \$1,3029	SBRT overall survival: 2.94 years Surgery overall survival: 3.39 years	Surgery vs. SBRT: \$2752/LYS

SBRT, stereotactic body radiation therapy; EBRT, external beam radiation therapy; 3DCRT, 3-dimensional conventional radiation therapy; IMRT, intensity modulated radiation therapy; RFA, radiofrequency ablation; USD, United States dollar; QALY, life years/life year saved; QALY, quality-adjusted life year; ICER, incremental cost-effectiveness ratio; ICUR, incremental cost-utility ratio.

SBRT ha costi comparabili alla 3D con migliori risultati

SBRT ha miglior rapporto costo-efficacia rispetto alla CH e RFA

Conclusioni

- La indicazione alla RT delle oligometastasi polmonari è consolidata dall' esperienza
- I risultati migliori si ottengono nei pazienti a presentazione più favorevole:
 - Metastasi unica metacrona
 - Primitivo controllato
 - Istologia favorevole (mammella, colon-retto, sarcoma)
 - Volume ridotto
 - Assenza di metastasi extratoraciche
 - Limitati precedenti trattamenti chemioterapici