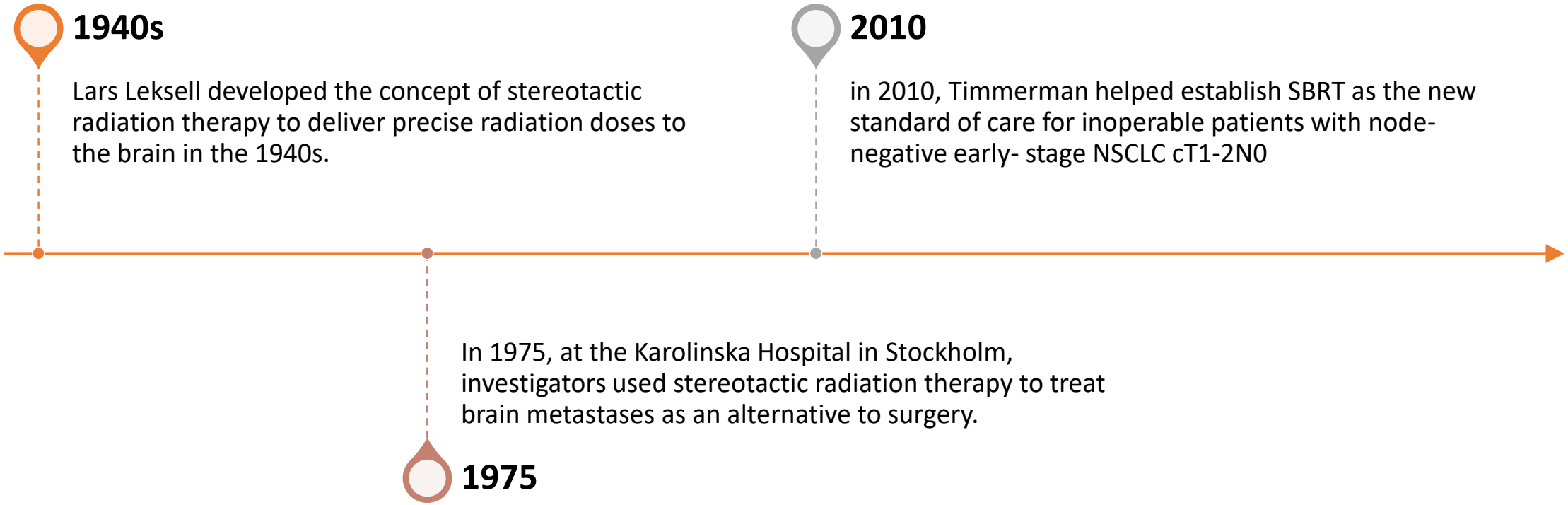
UNIVERSITÀ DEGLI STUDI DI MILANO

IMAGING FOR EXTRACRANIAL SBRT

Dott. Salvatore Alessio Angileri

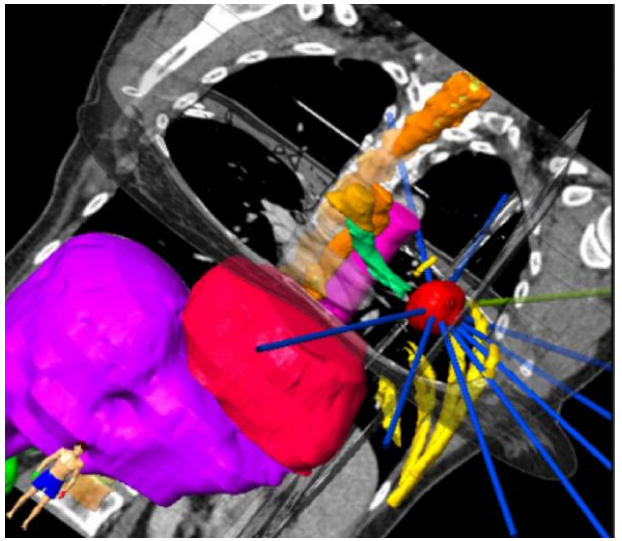
HISTORY

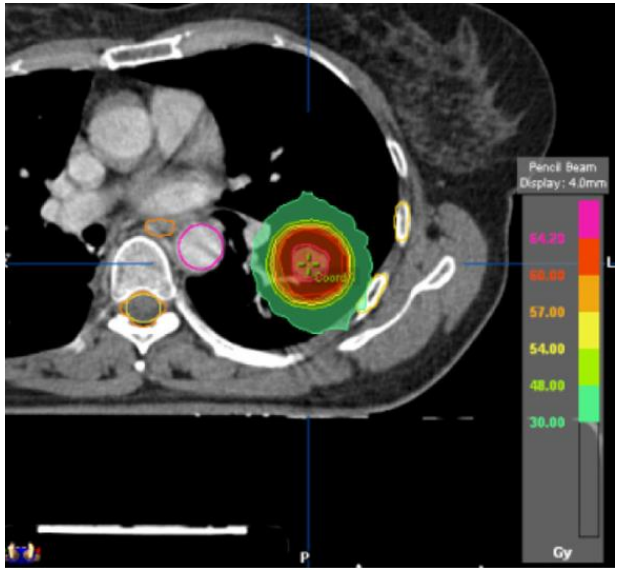


Transl Lung Cancer Res 2019;8(1):24-31

PROCESS OF SBRT

- Acquisition of planning images in the treatment position.
- Delineation of target volumes and normal organs at risk (OARs), after transferring CT/MRI images to the RT treatment planning system;
- Verification of patient and tumor position, with orthogonal radiographs or cone-beam CT;
- Beginning of treatment.

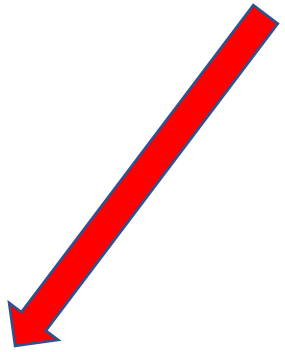




Yeungnam Univ J Med. 2019 Sep; 36(3): 192–200.
Rep Pract Oncol Radiother. 2013 Nov; 18(6): 387–396.

STRATEGIES TO OPTIMIZE SBRT

The goal of SBRT is to **accurately target the tumor** and deliver sufficient dose to **achieve local control** while **minimizing the dose to highly sensitive surrounding organs at risk** (OARs), with particular attention to immobilization of patients, precise target localization and tumor motion management.



MOTION MANAGEMENT

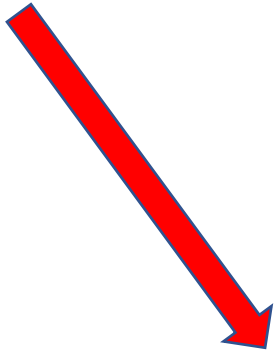


IMAGE GUIDANCE MODALITIES

Transl Lung Cancer Res 2019;8(1):24-31

STRATEGIES TO OPTIMIZE SBRT

1. MOTION MANAGEMENT STRATEGIES

- Breath-hold CT
- Slow CT
- Four dimensional CT scanning (4DCT)
  - Respiratory gating
  - Active breathing control
  - Abdominal compression, “dampering”
- Tumor tracking
  - By fluorocopic guidance;
  - By integration of MRI devices into RT machine;

Rep Pract Oncol Radiother. 2013 Nov; 18(6): 387–396.

Transl Lung Cancer Res 2019;8(1):24-31

STRATEGIES TO OPTIMIZE SBRT

2. IMAGE GUIDANCE STRATEGIES

- CBCT
  - As guidance during treatment;
  - Provides volumetric imaging;
  - Permits patients setup and correction of positional errors based on an assessment of 3D soft tissue anatomy compared to the planning scan.
  - Limitations: helical scattering and longer acquisition time
- 4D CBCT
- MRI
  - As modality for pre-treatment acquisition;
  - As guidance during treatment;
  - Utility of ADC values on post-treatment MRI to predict local recurrence.
  - Better soft tissue contrast, lack of radiations;
  - Limitations: motion and susceptibility artifacts;

Transl Lung Cancer Res 2019;8(1):24-31

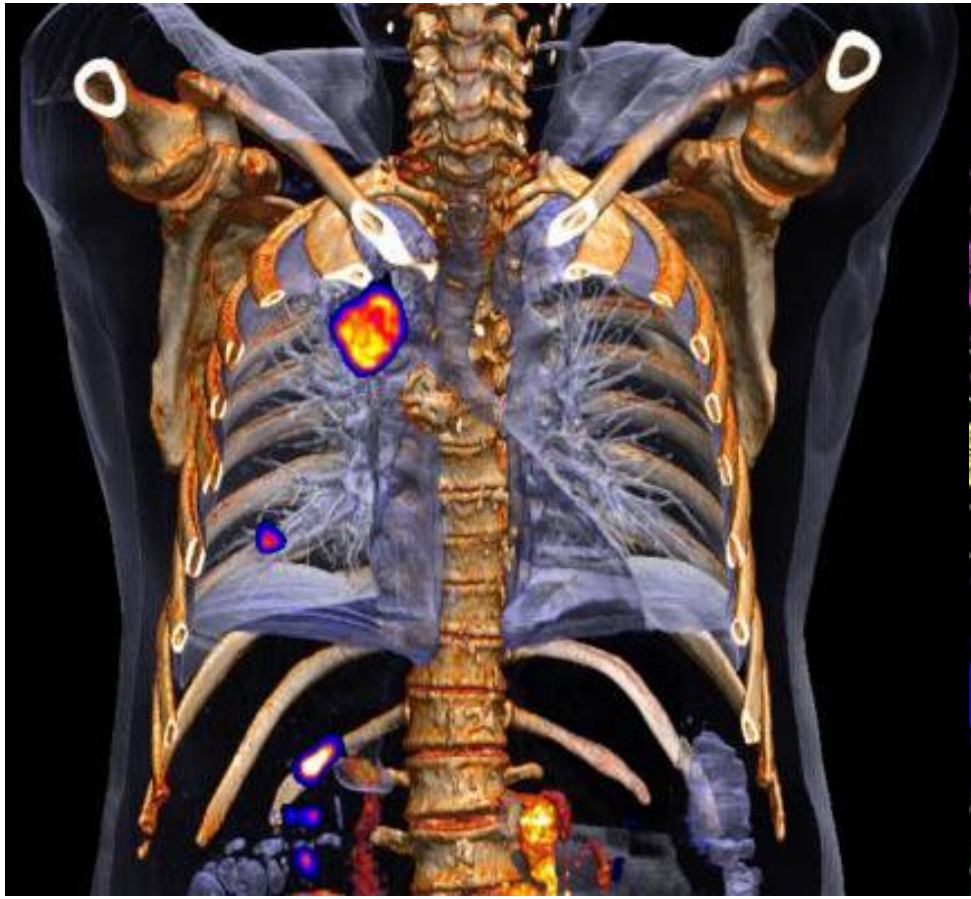
INDICATIONS OF SBRT

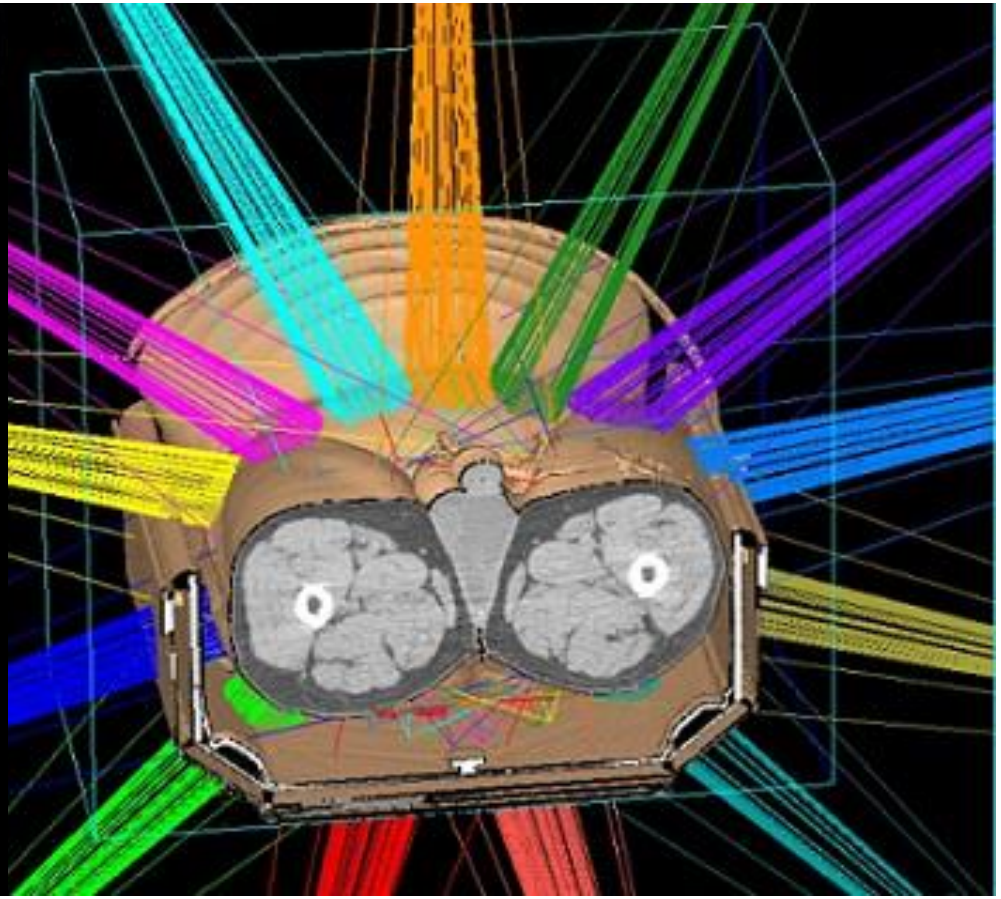
- In medically inoperable patients due to excellent disease control rates;
- In operable patients, as alternative to surgical resection;
- in patients with oligometastatic disease as excellently effective treatment for small lesions.

Transl Lung Cancer Res 2019;8(1):24-31

EXTRACRANIAL TARGETs OF SBRT

1. LIVER
2. PANCREAS
3. SPINE
4. HEAD AND NECK
5. PROSTATE
6. PELVIS
7. LUNG





EXTRACRANIAL APPLICATION OF SBRT

1. LIVER
   - To **Child Pugh A or B7** patients, to avoid radiation induces liver disease (RIDL)
   - As a bridge therapy, to prevent tumor progression while waiting for transplantation or to downstage tumors into the Milano criteria, not increasing surgical complication;
   - In advanced HCC
     - To restore the portal flow to facilitate subsequent treatment;
     - Increasing the clinical outcomes when combined with TACE for large HCC
   - In combination with systemic therapies, due to frequent intrahepatic or extrahepatic recurrences after SBRT.

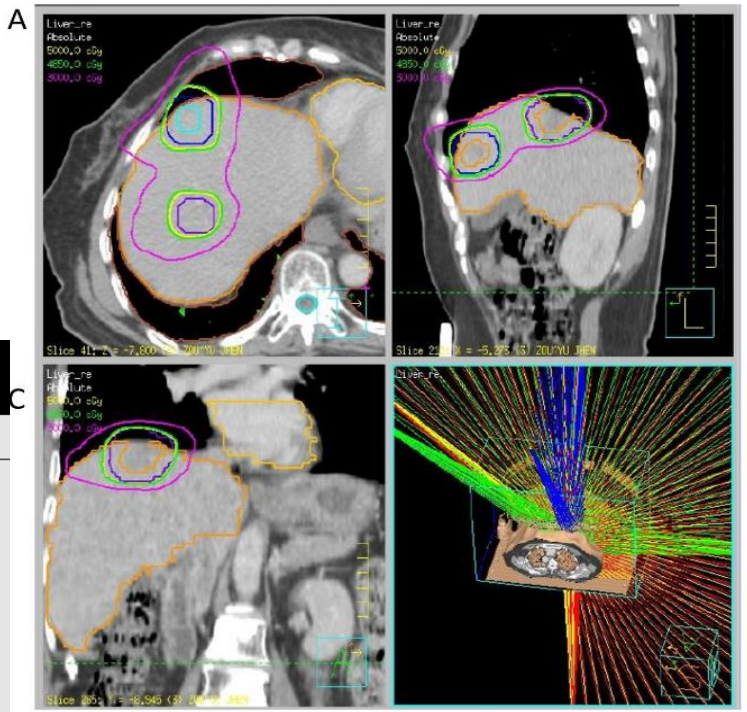


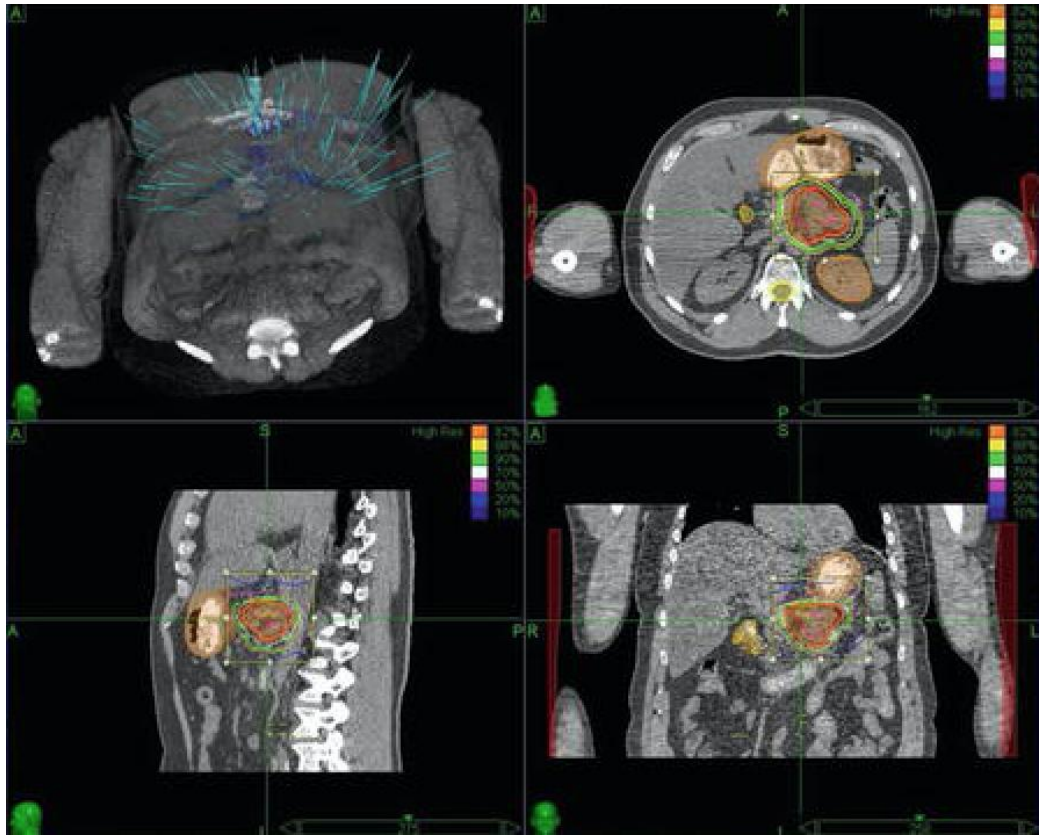
Table 2 – Selected published series of stereotactic body radiotherapy for primary liver tumors. Retrospective and phase I–II studies.

Author	Patients	Study	Doses	Local control	Toxicity
Blomgren 1998[16]	11	Retrospective	30 Gy 2–5 fx	1 year 95%	10% grade ≥ 3HCC Child B
Mendez Romero 2006[41]	8	Prospective	25–37.5 Gy/3–5 fx	1 year 75%	18% grade ≥ 3HCC Child B
Choi 2006[42]	20	Prospective	50 Gy/5 fx	1 year 80%	No grade ≥ 3
Tse 2008[43]	31	Prospective	36 Gy/6 fx	1 year 65%	16% grade ≥ 3HCC Child B
Cardenes 2008[44,45]	17	Prospective	36–48 Gy/3fx Child A40 Gy/3 fx Child B	1 year 96%	18% grade ≥ 3HCC Child B
Dewas 2012[48]	42	Retrospective	40–45 Gy/3 fx	2 years 90–5%	10% grade ≥ 3
Andolino 2011[46]	60	Retrospective	42 Gy/3 fx (Child A)40 Gy/5 fx (Child B)	2 years 90%	No grade ≥ 3
Andolino 2011[46]	60	Retrospective	42 Gy/3 fx (Child A)40 Gy/5 fx (Child B)	2 years 90%	No grade ≥ 3

Rep Pract Oncol Radiother. 2013 Nov; 18(6): 387–396
Yeungnam Univ J Med. 2019 Sep; 36(3): 192–200

EXTRACRANIAL APPLICATION OF SBRT

2. PANCREAS
   - Local advanced cancer without mestasis;
   - Combination with chemiotherapy for systemic control.



PLOS ONE

RESEARCH ARTICLE

Stereotactic body radiation therapy for locally advanced pancreatic cancer

Jinhong Jung[1], Sang Min Yoon[1], Jin-hong Park[1☯*], Dong-Wan Seo[2☯*], Sang Soo Lee[2☯*], Myung-Hwan Kim[2], Sung Koo Lee[2], Do Hyun Park[2], Tae Jun Song[2], Baek-Yeol Ryoo[3], Heung-Moon Chang[3], Kyu-pyo Kim[3], Changhoon Yoo[3], Jae Ho Jeong[3], Song Cheol Kim[4], Dae Wook Hwang[4], Jae Hoon Lee[4], Ki Byung Song[4], Yoon Young Jo[1], Jongmoo Park[5], Jong Hoon Kim[1]

Conclusions

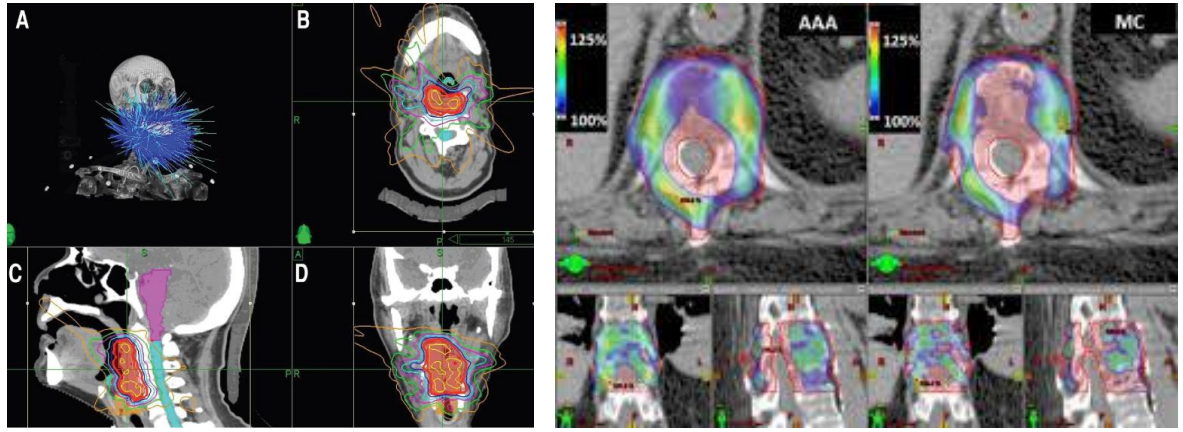
LAPC patients who received chemotherapy and SBRT had favorable FFLP and OS with minimal treatment-related toxicity. The most common pattern of failure was distant metastasis, which warrants further studies on the optimal scheme of chemotherapy and SBRT.

Rep Pract Oncol Radiother. 2013 Nov; 18(6): 387–396.

EXTRACRANIAL APPLICATION OF SBRT

3. SPINE
   - Prevalently In metastatic disease.

4. HEAD AND NECK
   - For recurrence of tumors firstly treated with radiation therapy, not suitable for conventional RT or surgical salvage;
   - In selective cases due to development of late toxicity.



REPORTS OF PRACTICAL ONCOLOGY AND RADIOTHERAPY 18 (2013) 387–396

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: http://www.elsevier.com/locate/rpor
ELSEVIER

Review

Extracranial stereotactic body radiotherapy. Review of main SBRT features and indications in primary tumors

Carmen Rubio[a,*], *Rosa Morera*[b,*], *Ovidio Hernando*[a], *Thomas. Leroy*[c], *S. Eric Lartigau*[c,*]

Review

Stereotactic Body Radiation Therapy for Spinal Malignancies

Virginia W. Osborn, MD[1,2], Anna Lee, MD, MPH[1,2], and Yoshiya Yamada, MD[1]

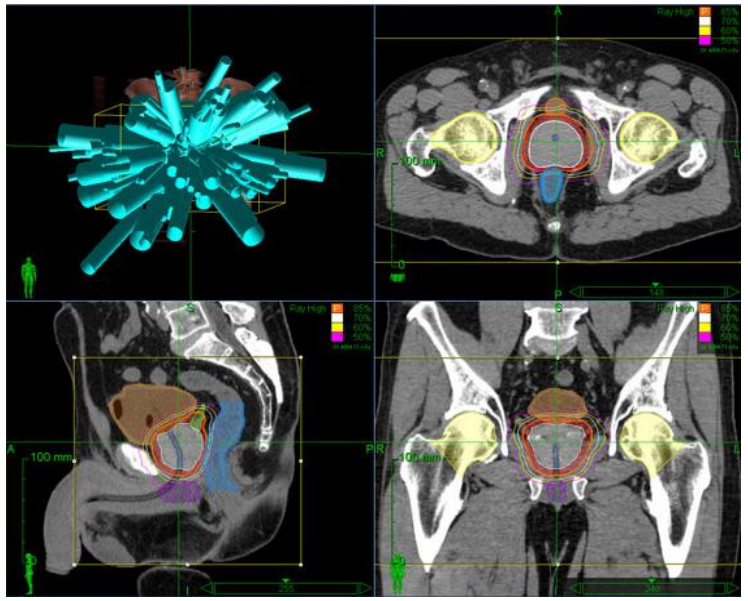
Technology in Cancer Research & Treatment
Volume 17: 1-15

DOI: 10.1177/1533033818802304
journals.sagepub.com/home/tct
SAGE

EXTRACRANIAL APPLICATION OF SBRT

5. PROSTATE
   - All patients are elegible;
   - Comparable to surgery in most localized tumors.

6. PELVIC REIRRADIATION
   - For recurrence of tumors firstly treated with radiation therapy, not suitable for conventional RT or surgery;
   - For lateral recurrence or proximity of the iliac vessels.



Reirradiation for isolated local recurrence of prostate cancer: Mono-institutional series of 64 patients treated with salvage stereotactic body radiotherapy (SBRT)

[1,2]BARBARA ALICJA JERECZEK-FOSSA, MD, PhD, [1,2]DAMARIS PATRICIA ROJAS, MD, [1]DARIO ZERINI, MD, [1]CRISTIANA FODOR, MSc, [1,2]ANNA VIOLA, MD, [1,2]GIUSEPPE FANETTI, MD, [1,2]STEFANIA VOLPE, MD, [3]ROSA LURASCHI, MSc, [3]ALESSIA BAZANI, MSc, [3]ELENA RONDI, MSc, [3]FEDERICA CATTANI, MSc, [1]ANDREA VAVASSORI, MD, [4]CRISTINA GARIBALDI, MSc, [5]SARAH ALESSI, MD, [5]PAOLA PRICOLO, MD, [5]GIUSEPPE PETRALIA, MD, [6]GABRIELE COZZI, MD, [6]OTTAVIO DE COBELLI, MD, [6]GENNARO MUSI, MD, [7]ROBERTO ORECCHIA, MD, [1]GIULIA MARVASO, MD and [1]DELIA CIARDO, MSc

Rep Pract Oncol Radiother. 2013 Nov; 18(6): 387–396.

EXTRACRANIAL APPLICATION OF SBRT

7. LUNG

CHEST IMAGING

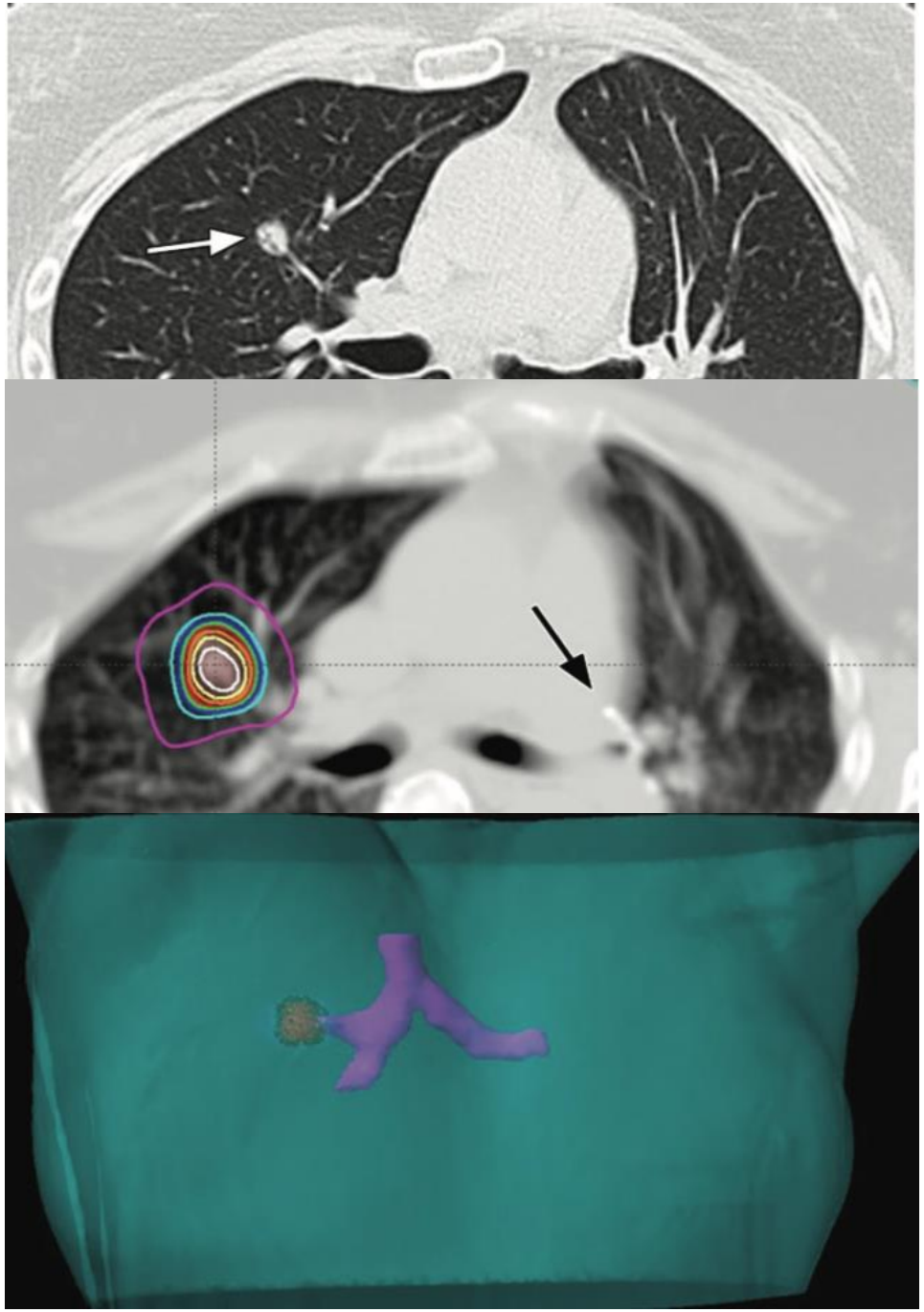
Stereotactic Body Radiation Therapy for Early-Stage Non–Small Cell Lung Cancer: A Primer for Radiologists

Established indications

- Early stage (T1-T2 N0M0) NSCLC in medically inoperable patients or patients who decline surgery
- Operable early-stage NSCLC in patients who decline surgery
- Locally recurrent NSCLC in previously irradiated lung or after surgery
- Multiple synchronous early-stage primary lung cancers

Indications that are currently being investigated

- Operable early-stage NSCLC



RadioGraphics 2018; 38:1312–1336 **55**

POST RADIATION LUNG CHANGES: SBRT VS Conventional RT

Characteristic of Lung Changes	After SBRT	After Conventional Radiation Therapy
Time of occurrence after completion of therapy	May be 6–12 wk or as long as 1 y*	Usually 4 wk
Scope of changes	Less extensive	More extensive
Location of changes	Usually confined to the high-dose region	Radiation portal including tumor as well as lung parenchyma surrounding tumor
Pattern of changes	May be masslike fibrosis pattern; the modified conventional fibrosis pattern can evolve into the masslike pattern	Conventional fibrosis pattern with straight anterior-posterior delineation, with air bronchograms and consolidation
Evolution of changes	Can continue to evolve >24 mo after therapy, although evolution beyond 48 mo is rare	Evolving changes >24 mo after therapy are not usual

Sources.—References 30, 31.
*Sometimes no CT change is depicted in the parenchyma surrounding the treated neoplasm after SBRT.

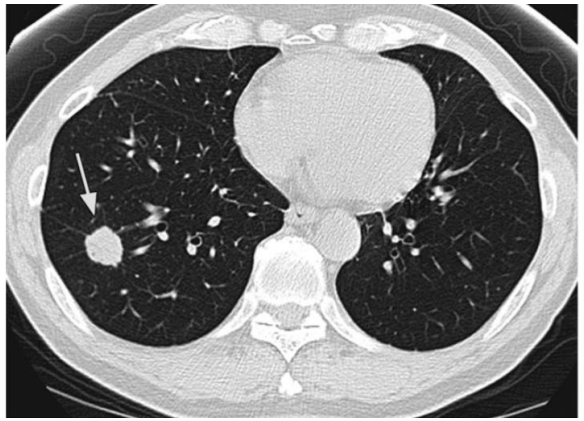
POST RADIATION LUNG CHANGES AFTER SBRT

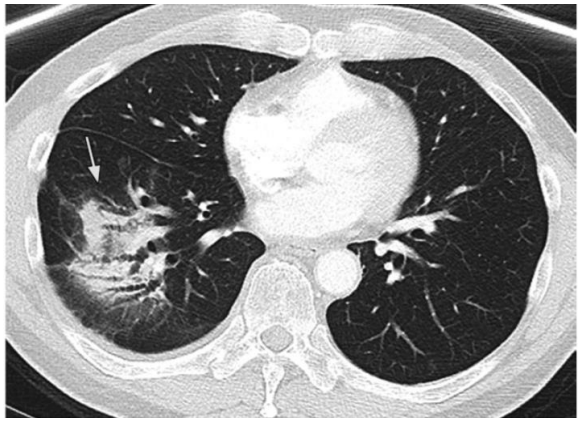
Early: up to 6 months **IKEZOE CLASSIFICATION**

- Diffuse consolidation pattern 45%
- Diffuse ground-glass pattern
- Patchy ground-glass pattern
- Patchy consolidation and ground-glass pattern
- No change

Late: after 6 months **KOENIG CLASSIFICATION**

- Modified conventional pattern 62%
- Scarlike pattern
- Masslike pattern
- No change





RadioGraphics 2018; 38:1312–1336 **55**

RECURRENCE AFTER LUNG SBRT

- **Distant**
  - The most common form of treatment failure after SBRT for early-stage NSCLC;
  - Rate of 20%, similar to surgical;
  - Diagnosis based on evidence of new disease at remote sites (bone, adrenal gland, liver, intra or extrathoracic lymphnodes).

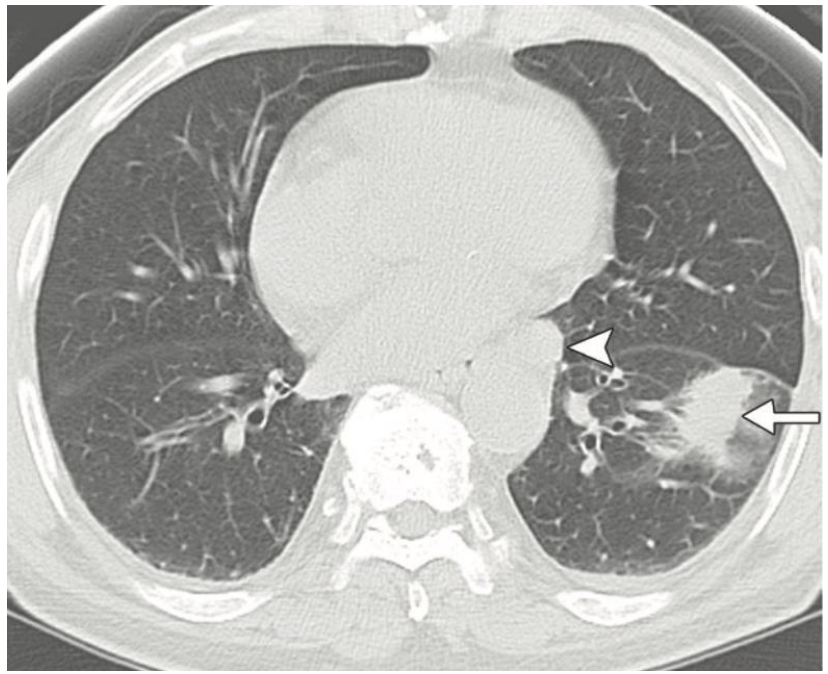
- **Regional**
  - Recurrence within local hilar and mediastinal lymphnodes, without recurrence in the treated field.

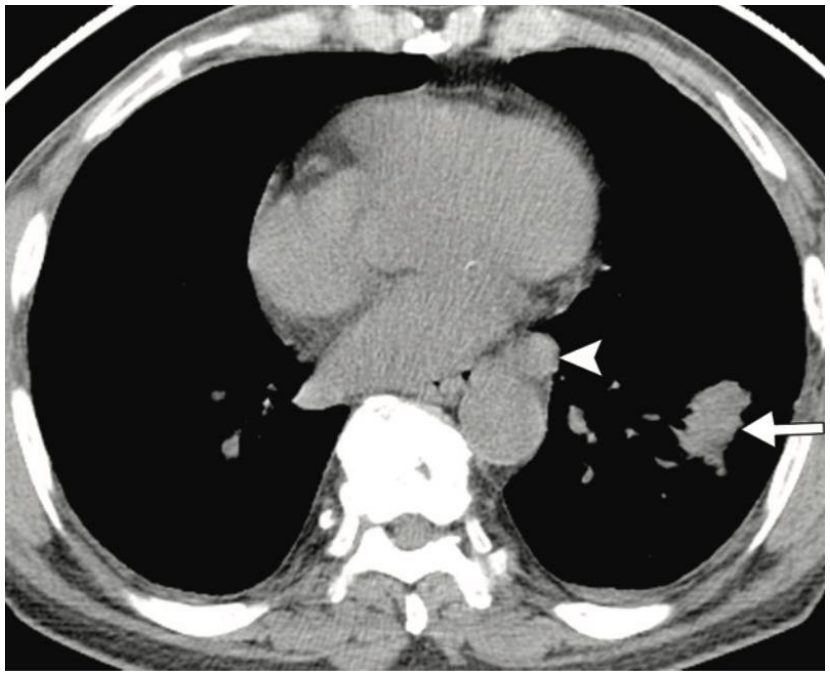
- **Local**
  - Recurrence in the treated neoplasm, adjacent to it, within the treatment fild or within the same lobe of the lung;
  - Generally within 3 years after treatment;
  - Predisponding factors: larger initial tumor volume, a squamous histologic subtype;
  - PET/CT findings showing residual FDG uptake with a maximum standardized uptake value (SUVmax) of 5 or greater at 12 weeks after SBRT are also predictive of poorer local control

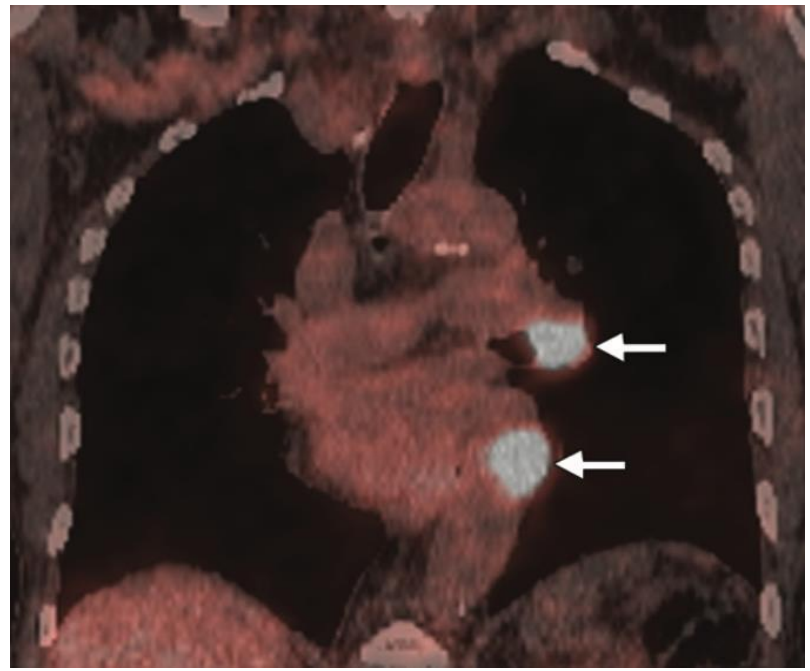
REGIONAL RECURRENCE AFTER SBRT

AXIAL CT 6 MONTHS AFTER SBRT

PET/CT







RadioGraphics 2018; 38:1312–1336 **55**

RECURRENCE AFTER LUNG SBRT

- **Distant**
  - The most common form of treatment failure after SBRT for early-stage NSCLC;
  - Rate of 20%, similar to surgical;
  - Diagnosis based on evidence of new disease at remote sites (bone, adrenal gland, liver, intra or extrathoracic lymphnodes).

- **Regional**
  - Recurrence within local hilar and mediastinal lymphnodes, without recurrence in the treated field.

- **Local**
  - Recurrence in the treated neoplasm, adjacent to it, within the treatment fild or within the same lobe of the lung;
  - Generally within 3 years after treatment;
  - Predisponding factors: larger initial tumor volume, a squamous histologic subtype;
  - PET/CT findings showing residual FDG uptake with a maximum standardized uptake value (SUVmax) of 5 or greater at 12 weeks after SBRT are also predictive of poorer local control

POST RADIATION LUNG CHANGES VS LOCAL RECURRENCE AFTER SBRT

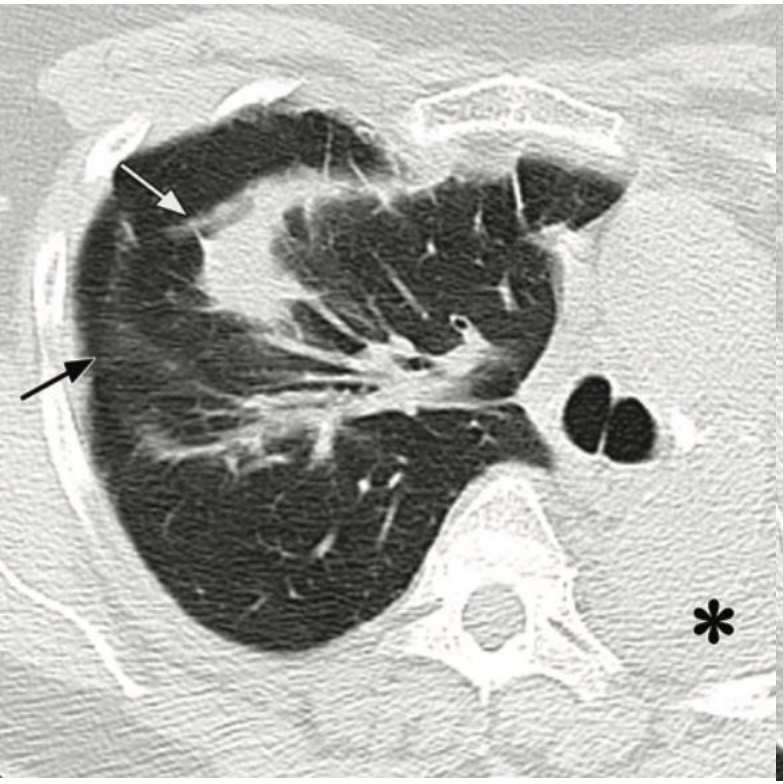
HUANG CRITERIA

Enlarging opacity at the SBRT site
Sequentially enlarging opacity
Loss of linear margin
Convex bulging margin
Disappearance of air bronchograms
Enlarging opacity without air bronchograms, particularly after 12 months
Craniocaudal growth ≥5 mm and ≥20%

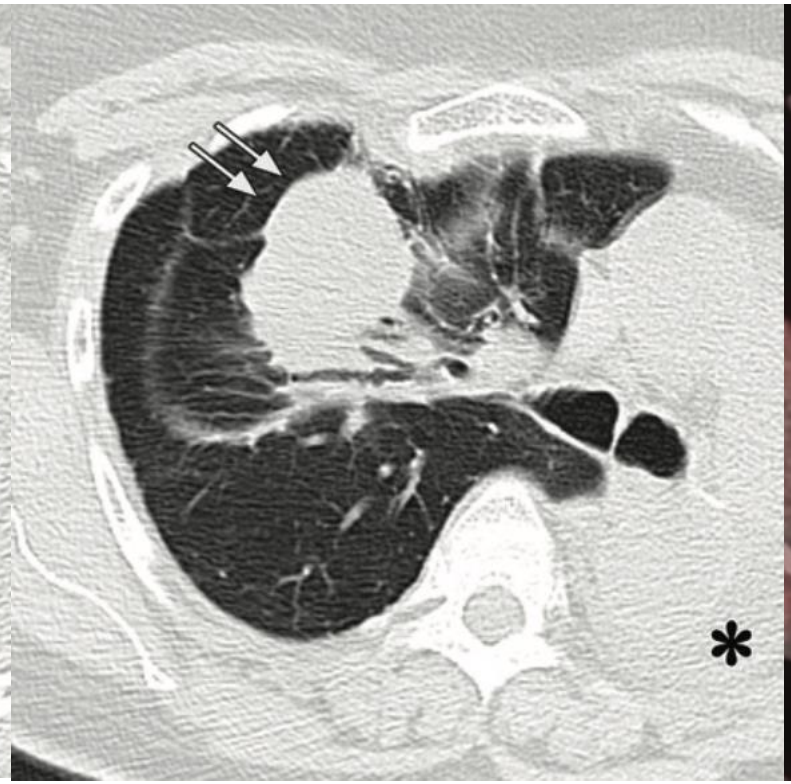
No. of High-Risk Features	Recommendation
0	Routine follow-up CT
1–2	PET/CT or close follow-up CT in 3 mo
≥3	PET/CT or biopsy or salvage therapy*

RadioGraphics 2018; 38:1312–1336 **55**
Radiother Oncol 2013;109(1):51–57.

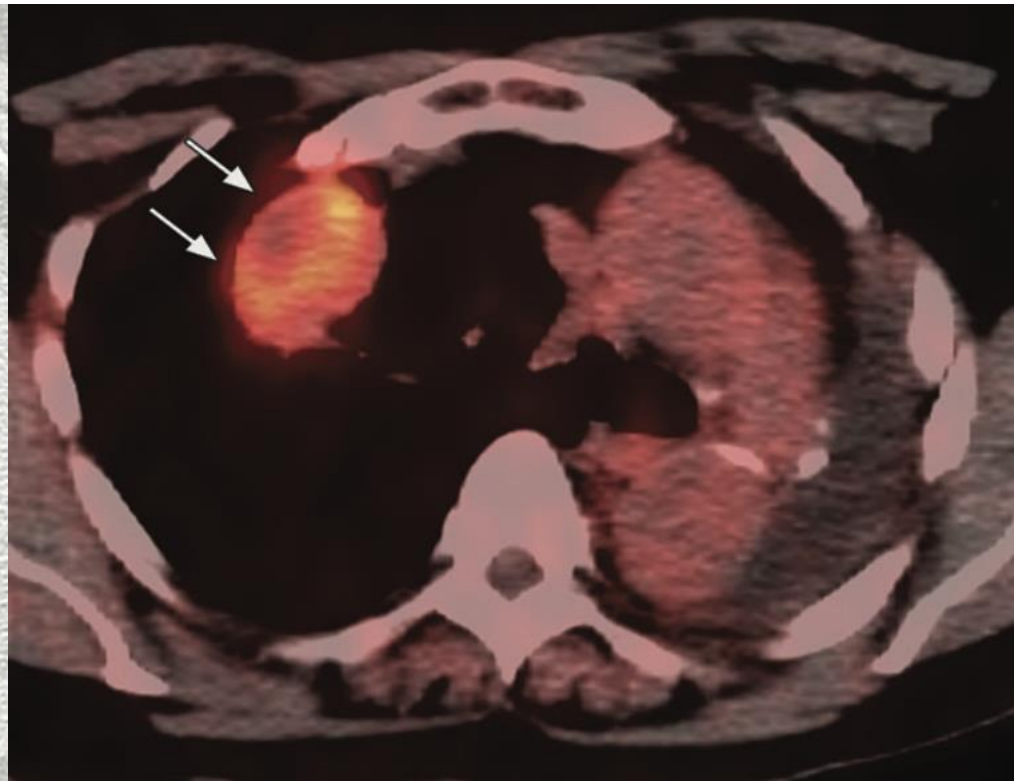
POST RADIATION LUNG CHANGES VS LOCAL RECURRENCE AFTER SBRT



8 months after SBRT



12 months after SBRT



PET/CT

LUNG SBRT – OTHER APPLICATIONS

- In oligometastatic disease, with curative intent;
- In oligoprogressive NSCLC;
- In treating stage I node negative small cell cancer, that manifests as a nodule, in patients not suitable or refusing surgery.

FUTURE DIRECTIONS

1. CT Texture Analysis
   - To early detect local recurrent disease;
   - To detect and quantify radiation injury in the lung
   - To differentiate them before it is possible to human eyes.

2. New PET/TC isotopes or PET/MRI

3. MRI
   - 3-6 months absolute ADC values after SBRT are lower in lesions that show subsequent recurrence.