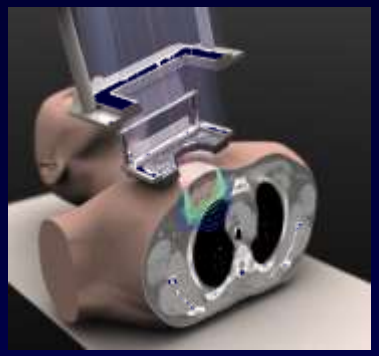
CONGRÈS
Imagerie Appliquée
à la Pratique Pneumologique

Ce n'est pas toujours une récidive: imagerie des traitements non chirurgicaux du cancer bronchique

Imagerie après radiothérapie

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Cliniques universitaires SAINT-LUC UCL BRUXELLES

Toulouse Club Thorax Septembre 2019

Ultimate goal of radiation therapy

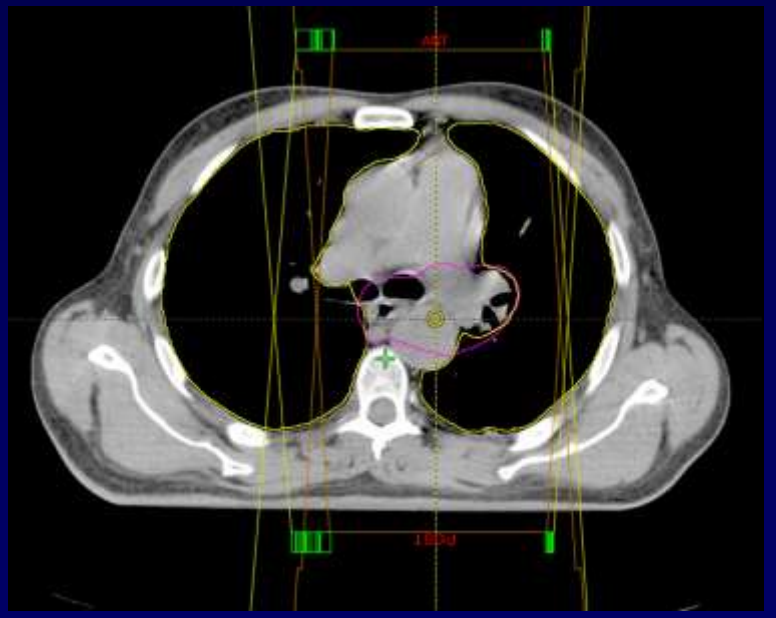
Eradicate all tumor cells

Avoid damage to healthy tissue

... to achieve tumor control without complication

Radiation therapy
How does it work

- **2D-conventional RT**
  - Two parallel beams with opposed orientations
  - 2 Gy per field combination per day
  - (≤) 60 Gy total
  - Limited beam orientation → large areas of normal tissue irradiated



Park RadioGraphics 2000;20:83

Radiation-induced lung disease

Reference point : day of completion of radiation therapy

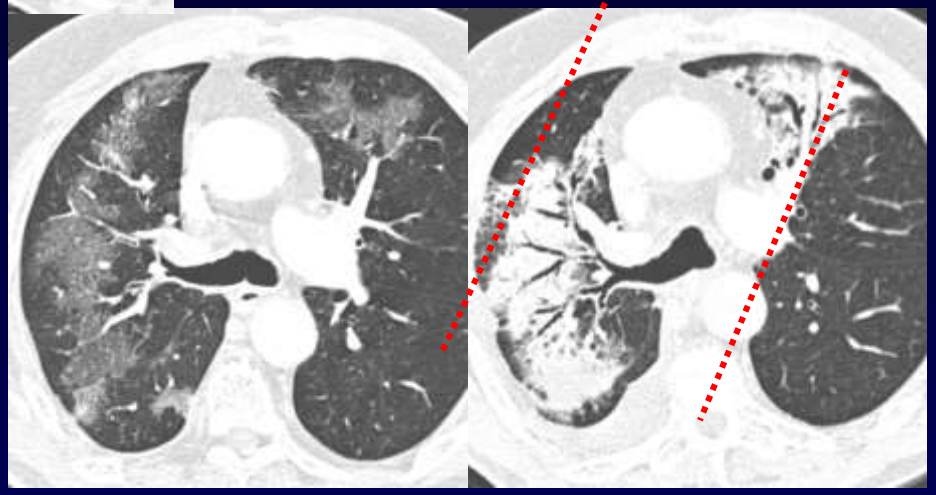
- **Early phase :** *transient radiation pneumonitis*
  - appears between 1 – 3 months
  - lasts up to 6 months
  - dyspnea, cough, low-grade fever, discomfort
  - steroids

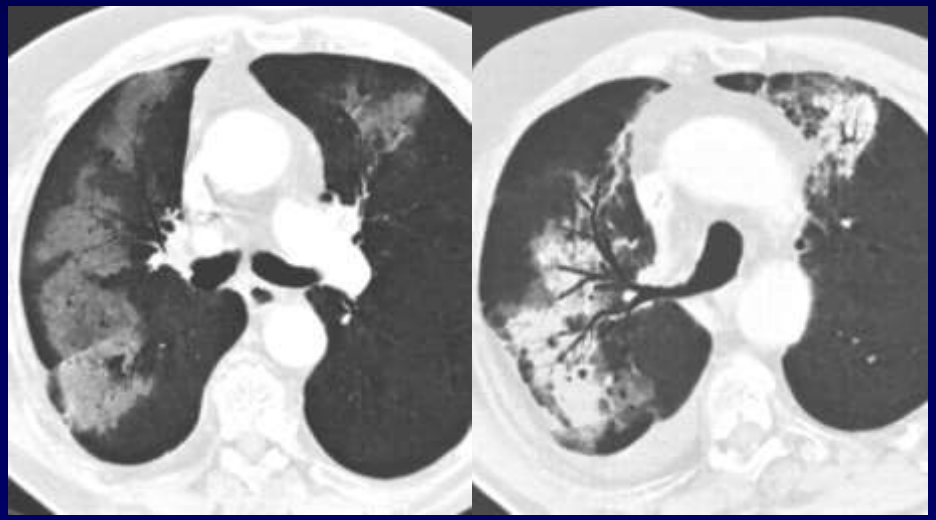
- **Late phase :** *chronic radiation fibrosis*
  - unresolved radiation pneumonitis
  - 6 - 12 months (up to 24 months)
  - stable after 2 years
  - mostly asymptomatic
  - progressive dyspnea, dry cough, cor pulmonale

Davis AJR 1992;159:1157
Park RadioGraphics 2000;20:83

2D - Radiation Therapy

Early phase





2 months 3 months

Pathology : acute exsudative phase followed by organizing phase with interstitial infiltration by mononuclear and other inflammatory cells

- Lung injury (diffuse / patchy / nodular)
  - Ground-glass
  - Consolidation

Generally confined to field of irradiation

Do not conform to anatomic boundaries

- Pleural effusion
- Atelectasis

- Usually regresses over 6 months

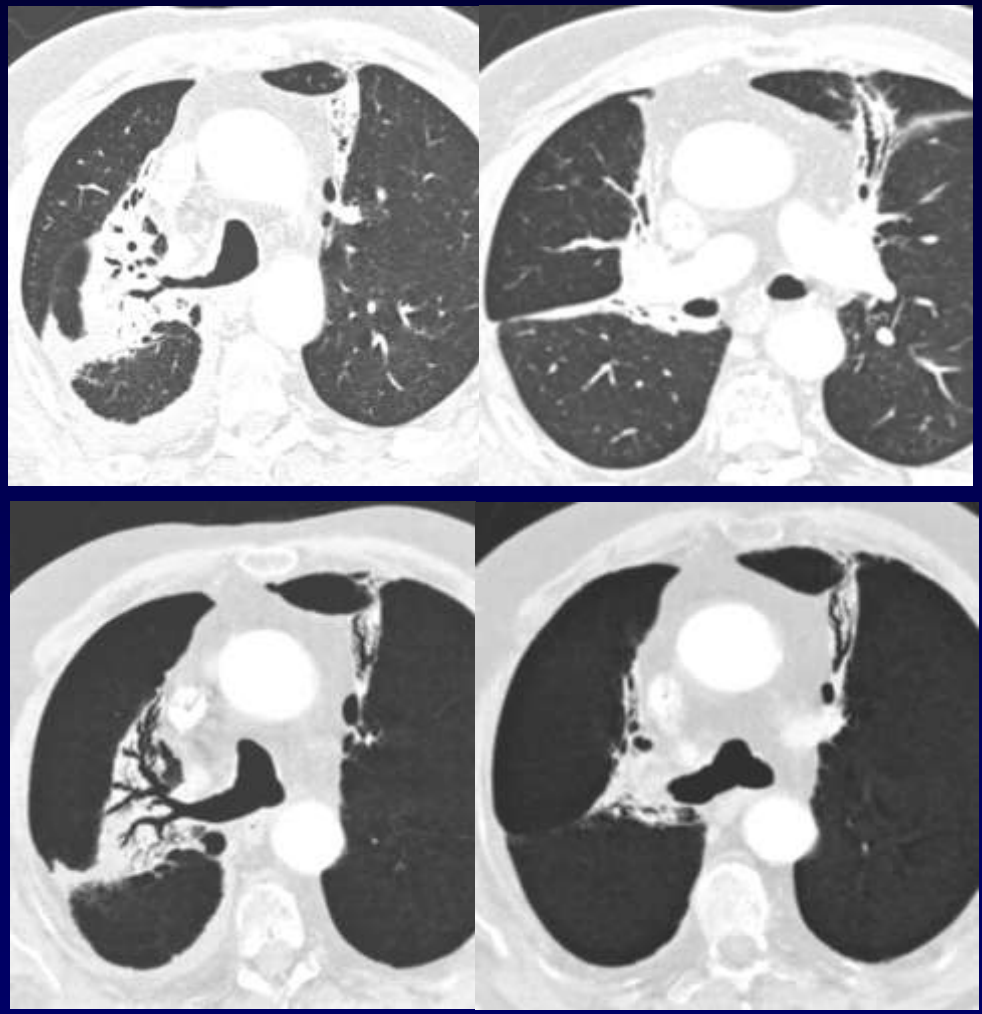
  No sequellae

Choi RadioGraphics 2004;24:985

2D - Radiation Therapy

- Lung volume loss (mediastinal shift)
  Architectural distortion
- Consolidation
  Well-defined
- Shrinkage
  Sharper demarcation
  Shape/location may change →12 mths
- Air bronchogram
  Traction bronchectasis
- May stabilize
  Evolve up to 24 mths
- (Small pleural effusion or thickening)

Late phase



8 months 10 months

Park RadioGraphics 2000;20:83
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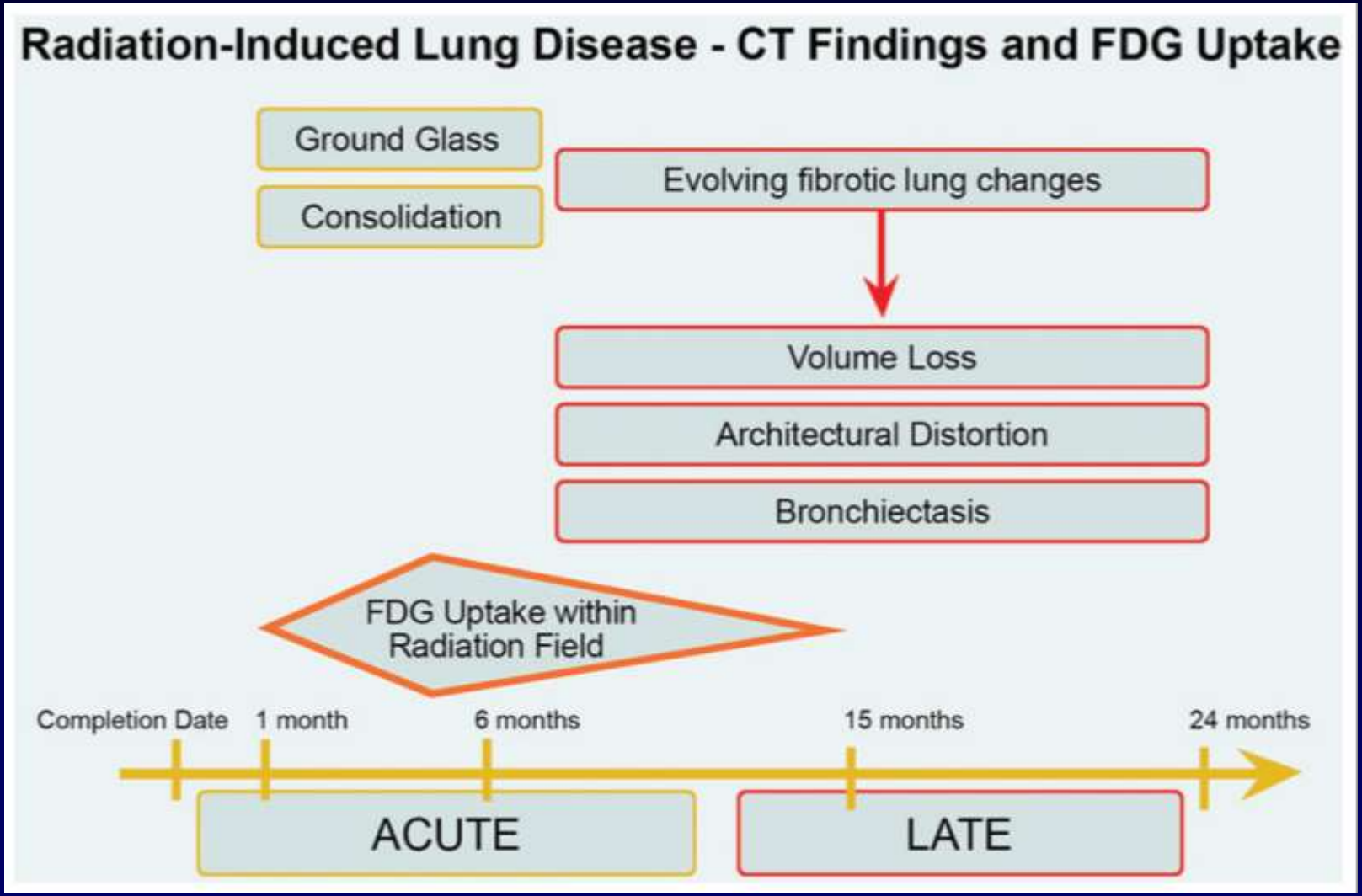
2D - Radiation Therapy

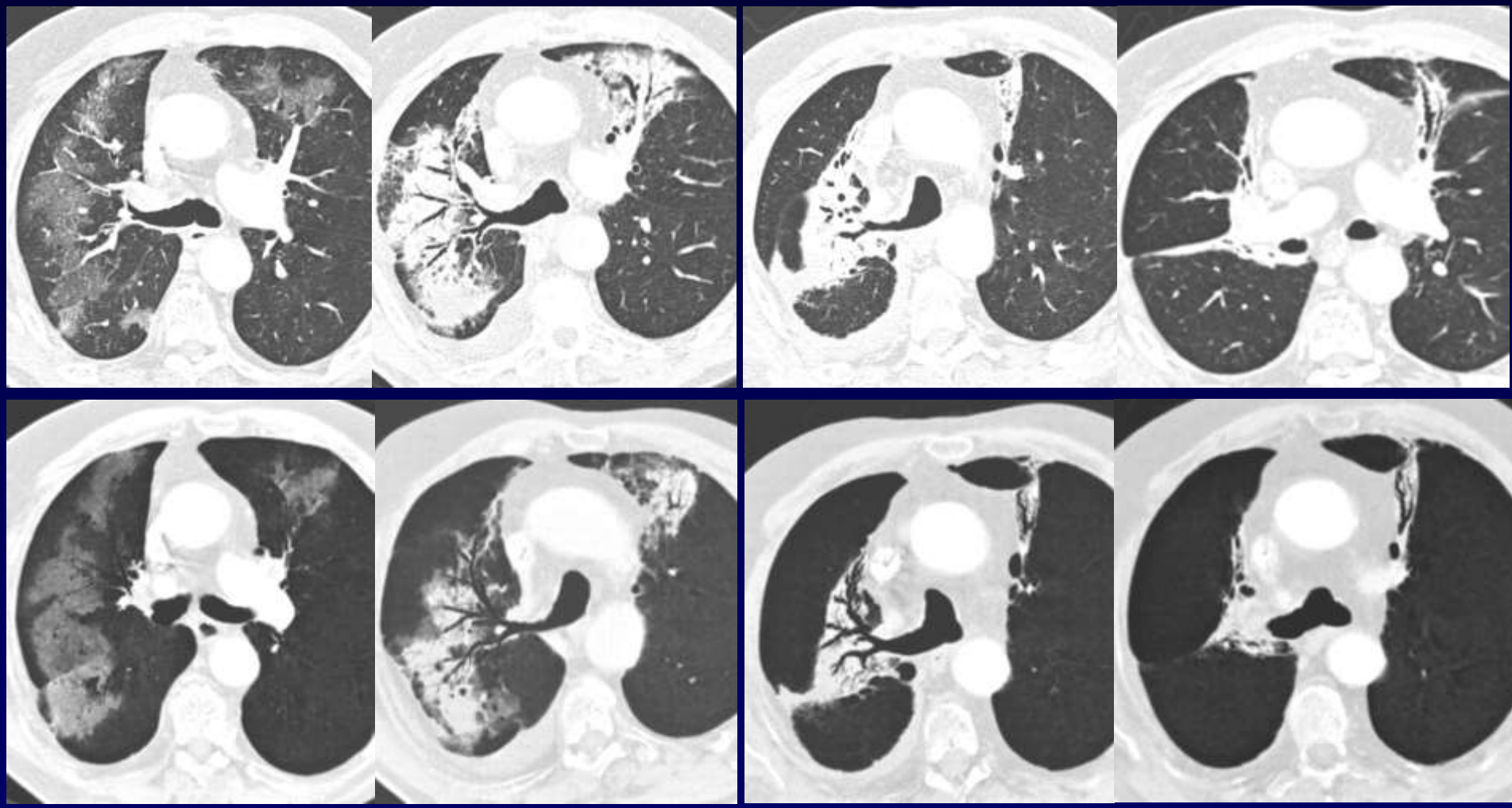


Benveniste RadioGraphics 2019;39:344

2D - Radiation Therapy

Early phase

Late phase



2 months

3 months

8 months

10 months

Radiation-induced lung disease

- Technique
  - Conventional *vs.* conformational
  - Portals and beam arrangement
  - Dose : total (rarely < 20, commonly 20-40, almost always > 40 Gy)
    fractionation and dose rate
  - Irradiated volume (V_{20Gy})
  - Physical characteristics of irradiation
- Treatment
  - Prior irradiation
  - Chemo, Immunotherapy
  - Steroids (rebound)
- Tumor
  - Tumor location
- Patient
  - Age
  - Lung performance status
  - Preexisting lung disease

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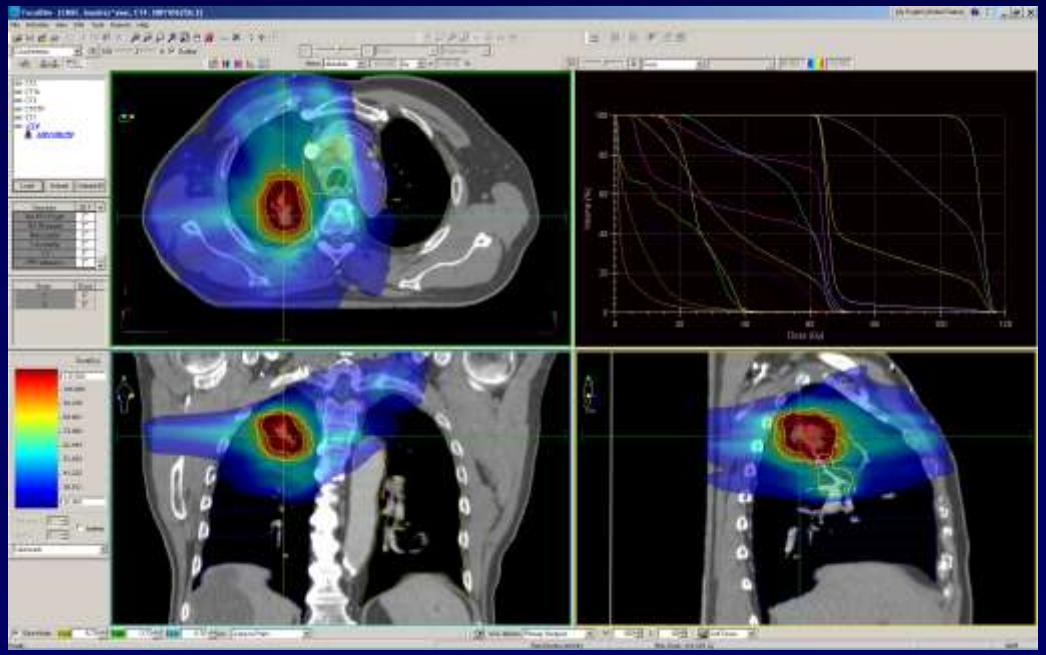

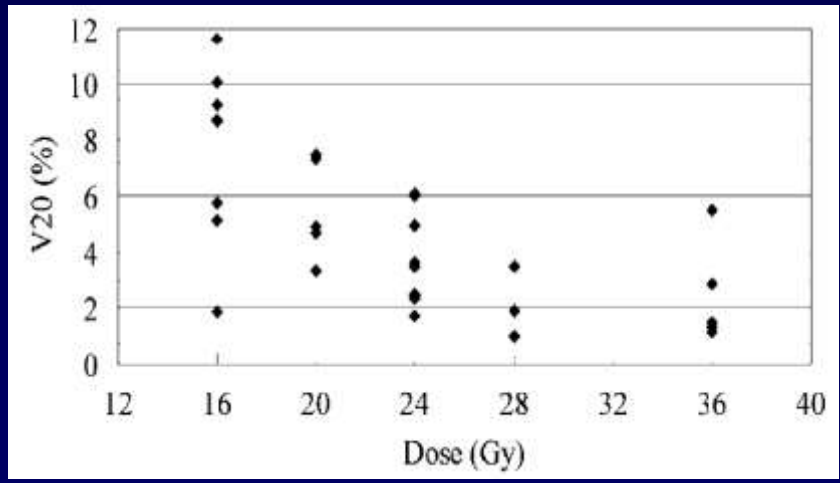

Aoki Radiology 2004;230:101

  - Preexisting lung disease

Park RadioGraphics 2000;20:83

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Benveniste Clin Radiol 2013;68:e275

Radiation therapy New techniques

3D-CRT

IMRT

SBRT

4D-RT

BOOST

PROTON

SABR

4D-PET-IGRT

Radiation therapy New techniques

3D-CRT

IMRT

SBRT

4D-RT

BOOST

PROTON

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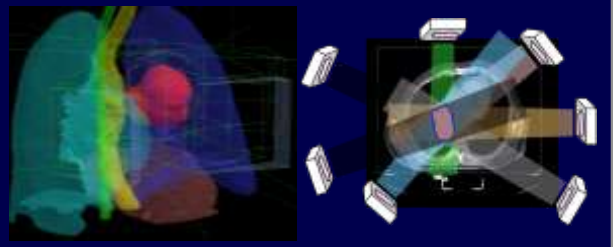
4D-PET-IGRT

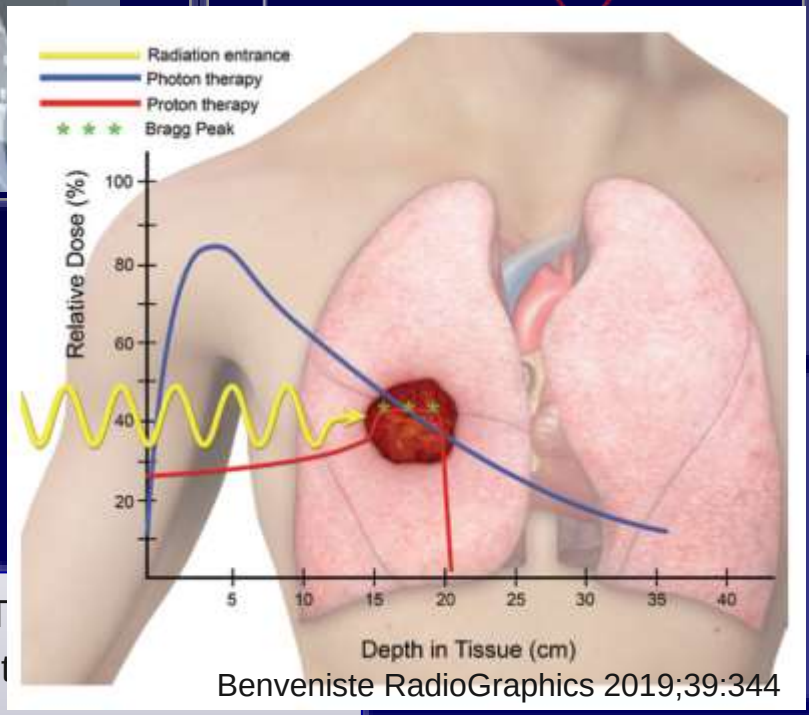
Radiation therapy New techniques

3D-CRT (3-dimensional conformal RT)



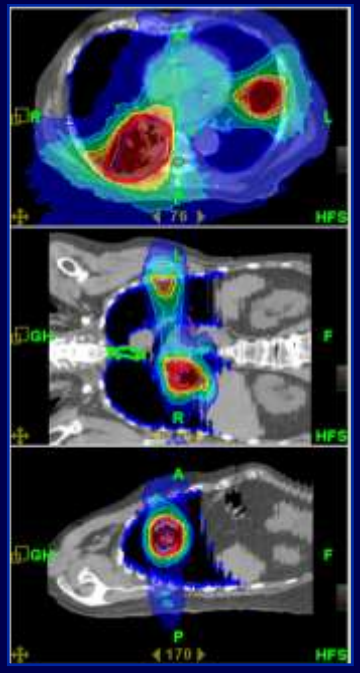
IMRT (intensity-modulated RT)

4D-RT (4-dimensional RT)



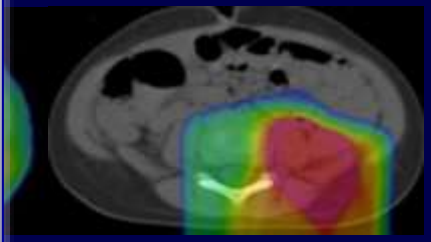
Benveniste RadioGraphics 2019;39:344

SBRT (stereotactic body RT)
SABR (stereotactic ablative RT)



- Smaller lesion (T1-T
- Steeper gradient bet
  low-dose areas
- Dose 10-20 Gy per fraction
  (hypofractionned scheme)
- 50-60 Gy
- 1-2 weeks
- 80-100% tumor local control

-based RT



Radiation-induced lung disease
Late or chronic phase

- Lung volume loss (mediastinal shift)
  Architectural distortion
- Consolidation
  Well-defined (modified conventional, scarlike, masslike patterns)
  Shape/location may change →12 mths
- Shrinkage
  Sharper demarcation
- Air bronchogram
  Traction bronchectasis
- May stabilize
  Evolve up to 24 mths
- (Small pleural effusion or thickening)

Koenig AJR 2002;178:1383-88
Larici RadioGraphics 2011;31:771-89

Radiation-induced lung disease
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Less extensive

- Consolidation
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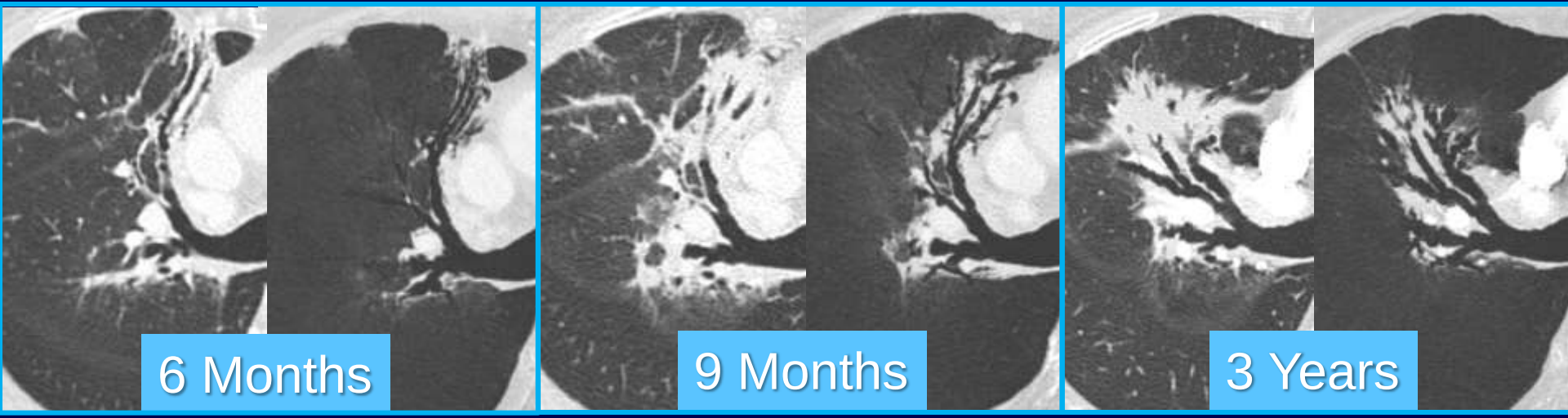

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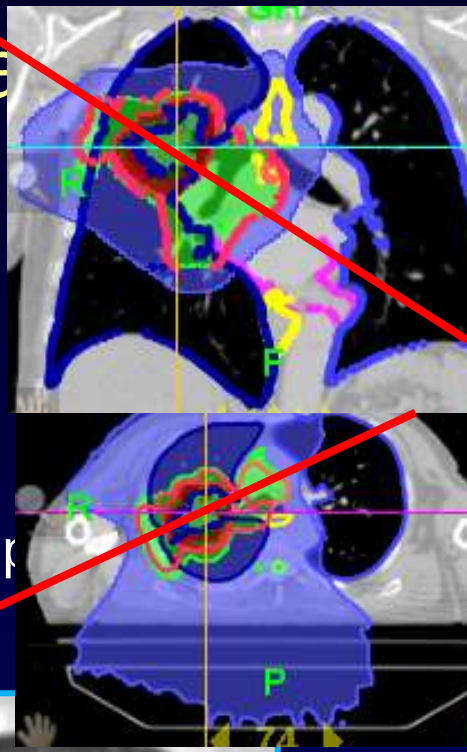

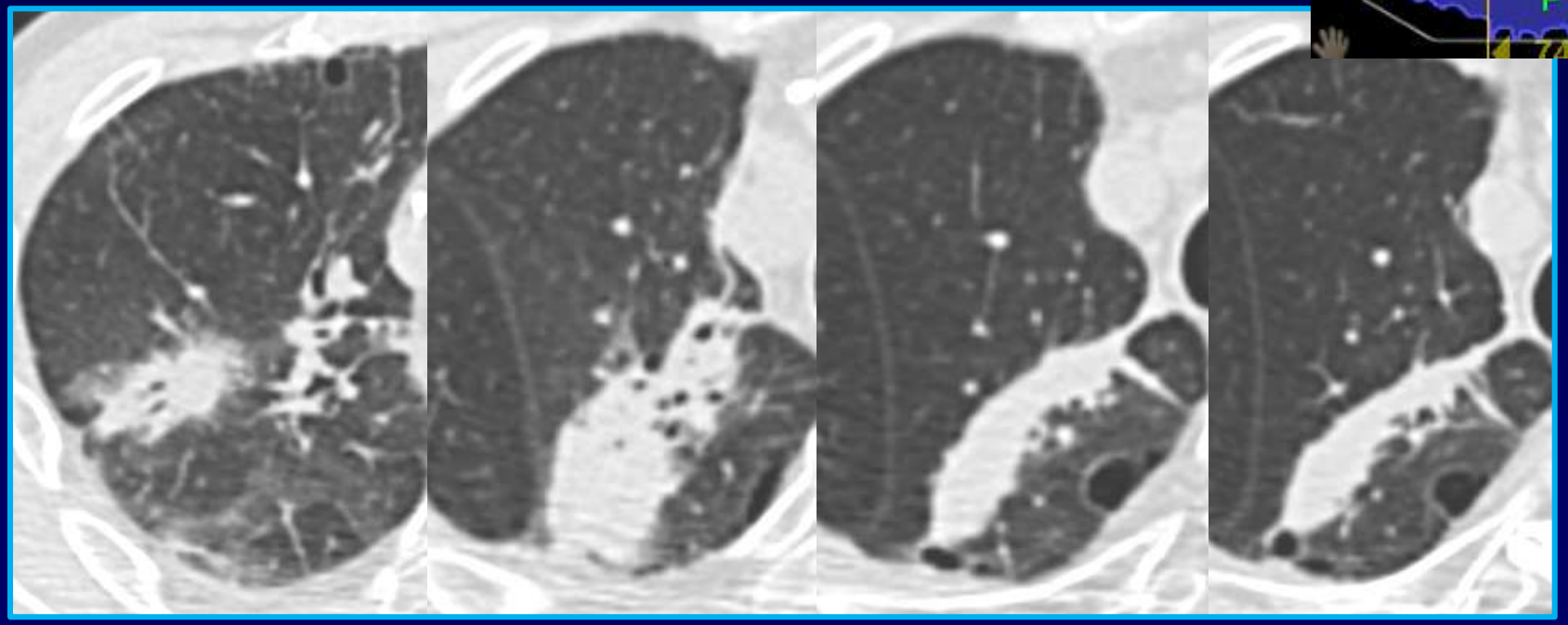

3 Months 6 Months 12 Months 18 Months

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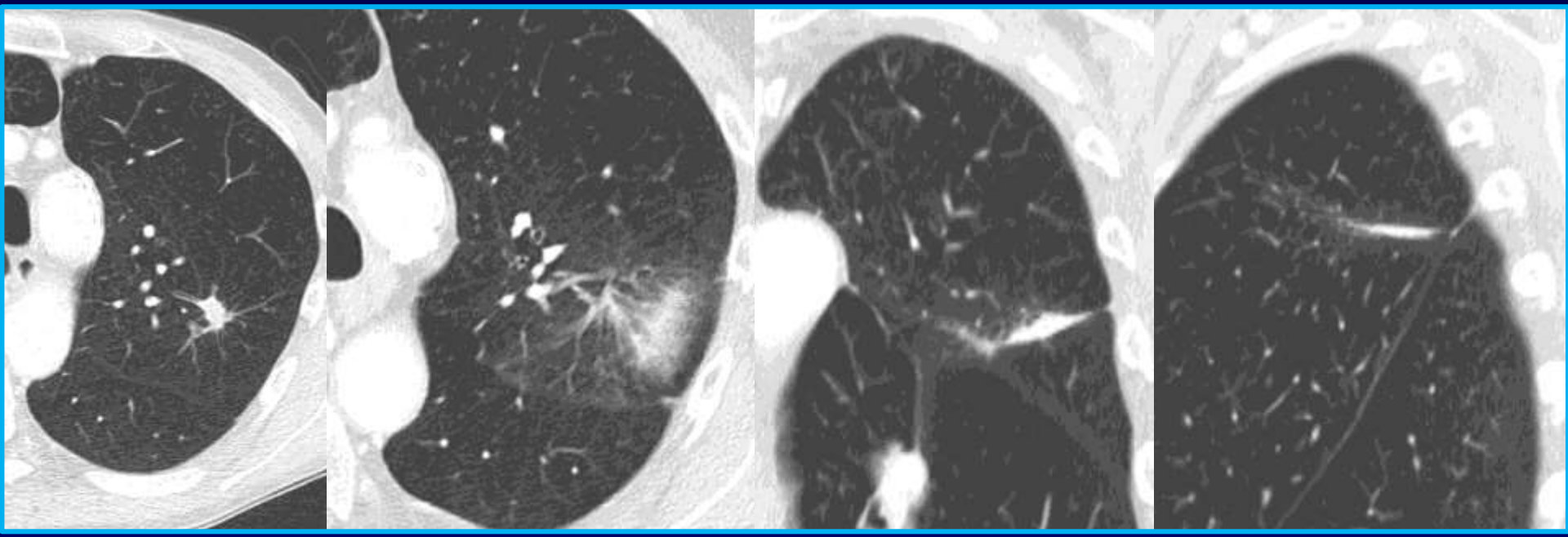

PRE POST

Larici RadioGraphics 2011;31:771-89

Radiation-induced lung disease
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May simulate tumor

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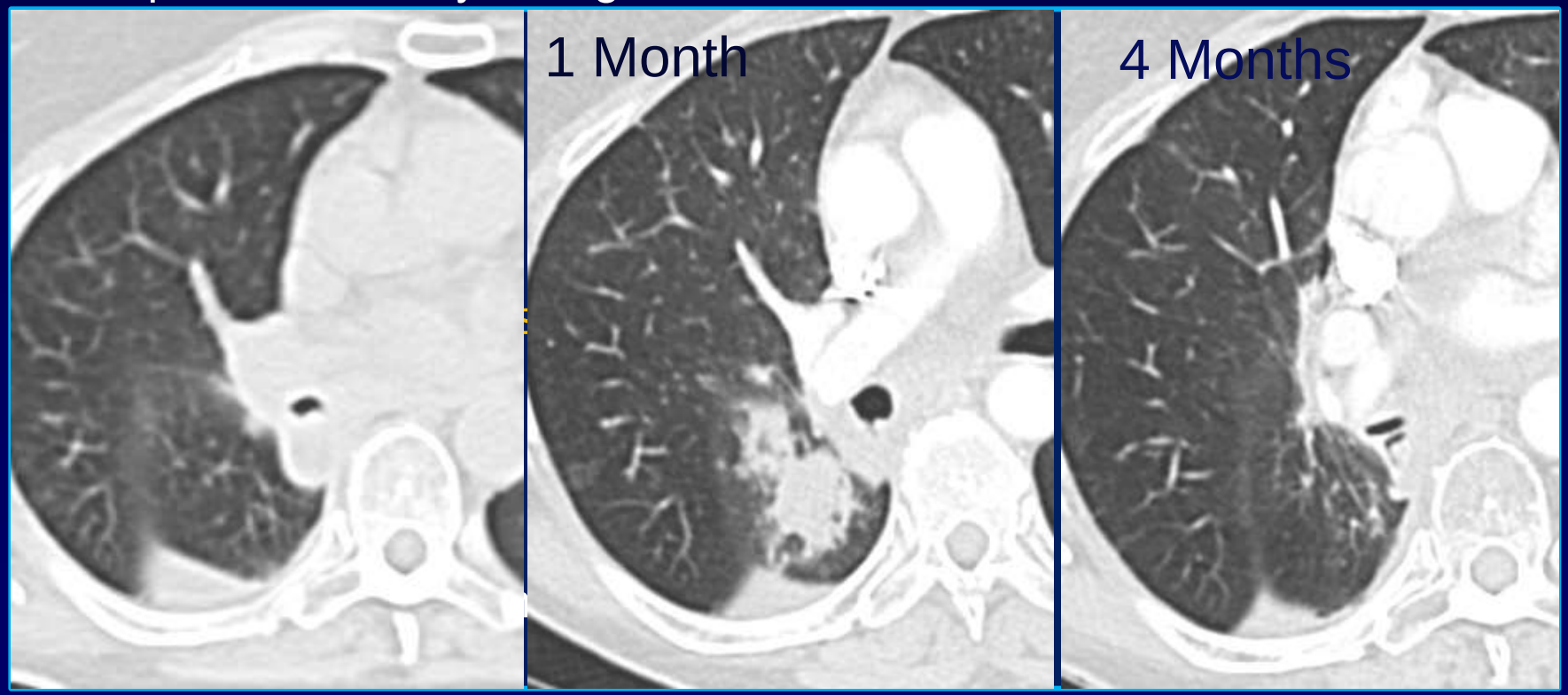

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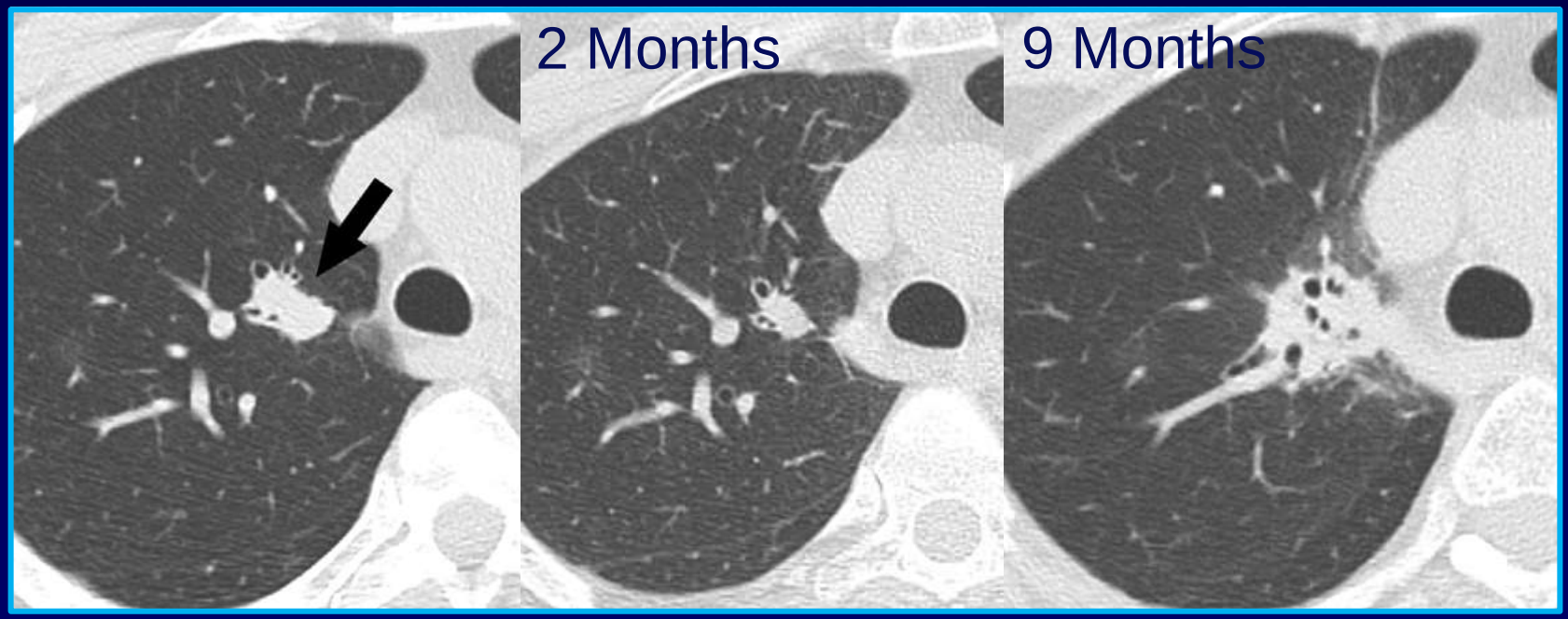


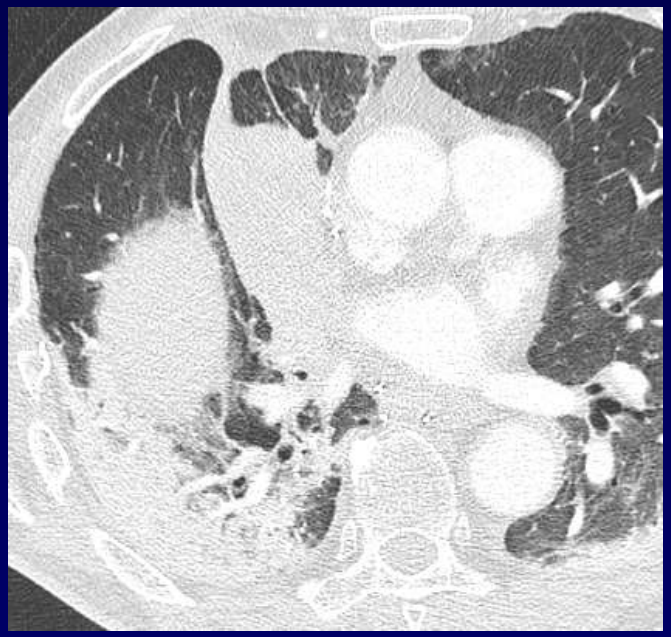
Dahele J Thorac Oncol 2011;6:1221-8
Ronden Int J Radiat Oncol Biol Phys 2018;100:115-21

Radiation-induced lung disease
Differential diagnosis

- Infections
- Locally recurrent tumor
- Radiation-induced tumor
- Drug-induced lung disease

Radiation-induced lung disease
Differential diagnosis

- Infections
  - Abrupt onset
  - Pulmonary opacities appearing before completion of RT outside radiation portals
  - Respect anatomic boudaries
  - Diffuse
  - Bilateral
  - Centrilobular, tree-in-bud opacities
  - Cavitation
  - Filling-in of bronchi
- Locally recurrent tumor
- Radiation-induced tumor

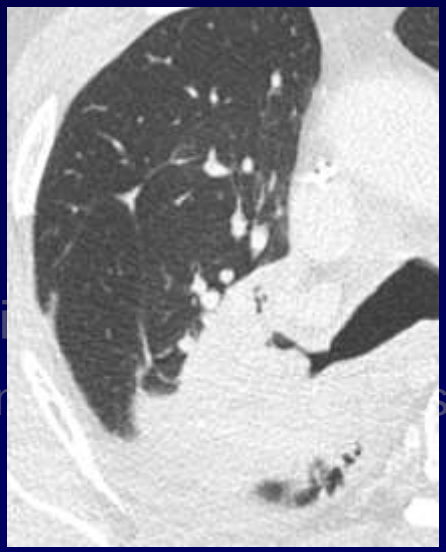


Choi RadioGraphics 2004;24:985

Radiation-induced lung disease
Differential diagnosis

- Infections
- Locally recurrent tumor
  - Usually within 2 years
  - Increase in size of radiation fibrosis area
  - Homogeneous opacification
  - Absence of air bronchogram
  - Convex border of irradiated lung
  - Filling-in of bronchi [2]
  - Others: LK, enlarging LN or pleural effusion
  - PET/CT >> CT : sensitivity 100% *vs.* 71%, speci
  - No PET before 3-6 months (PET uptake occasionn s)
  - Pathological proof required
- Radiation-induced tumor

5 Months



9 Months

[1]Kim RadioGraphics 1992;12:269
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[2]Libshitz Radiology 1999;210:25
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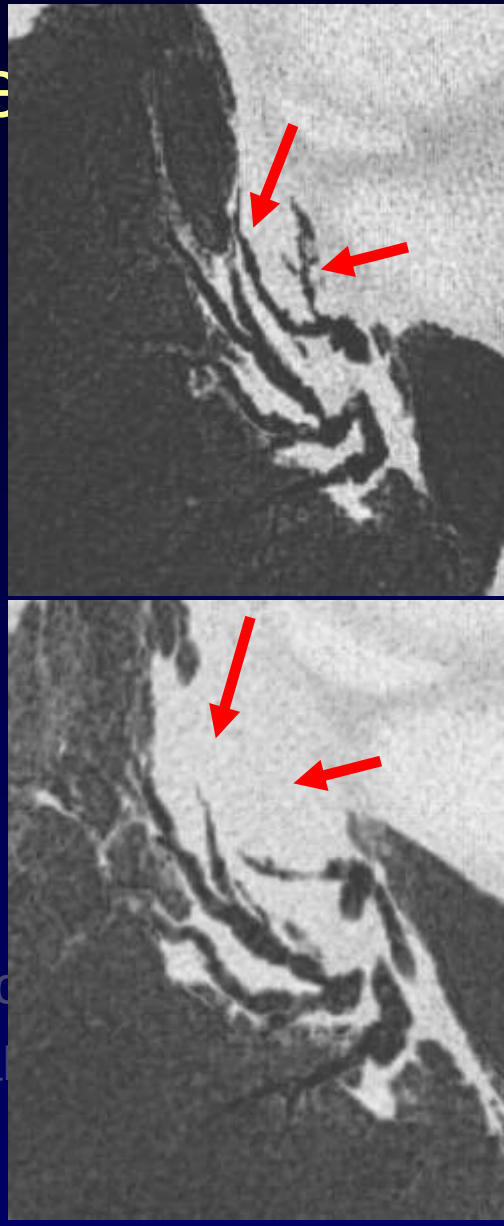

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Radiation-induced lung disease
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- Infection

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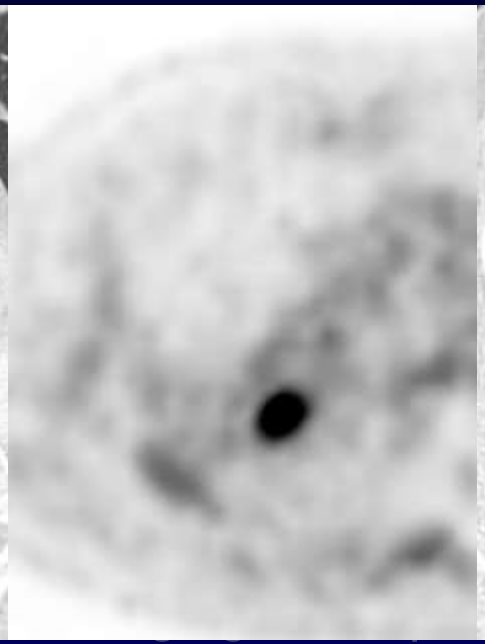

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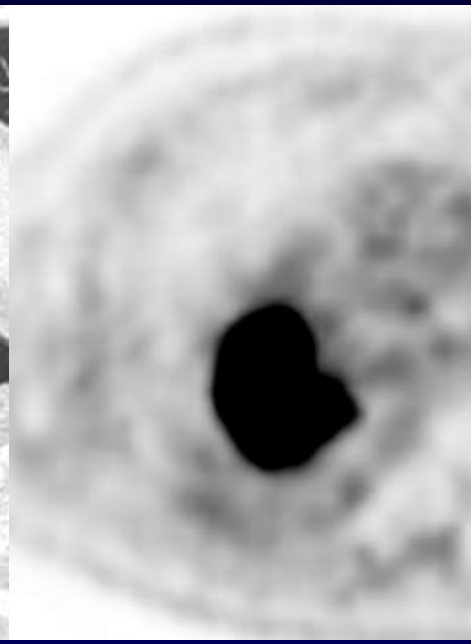

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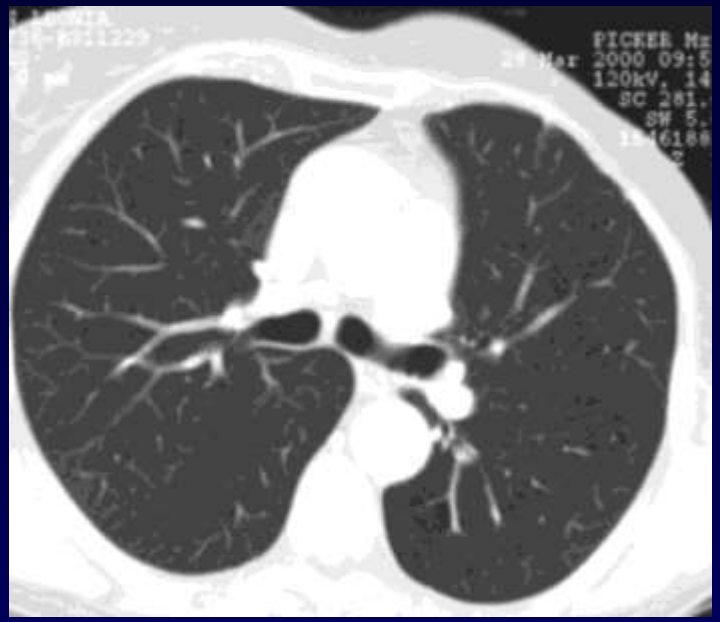
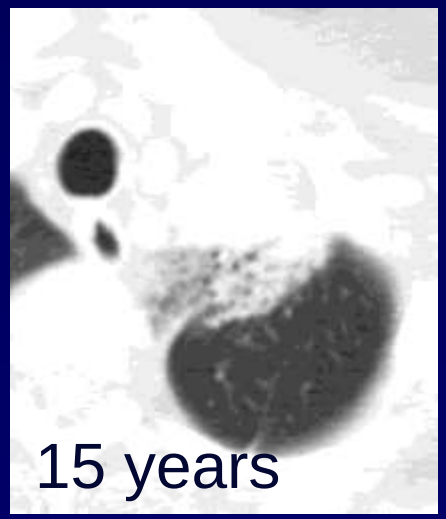
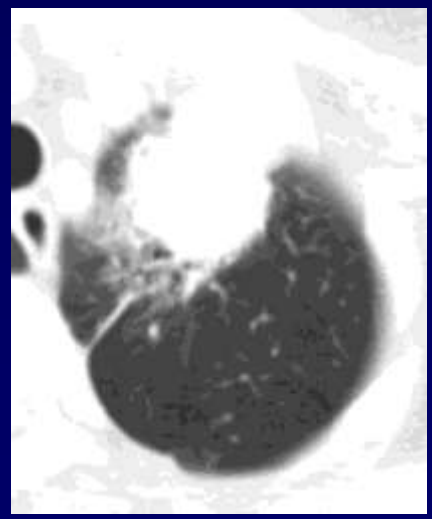
Radiation-induced lung disease
Differential diagnosis

- Infections
- Locally recurrent tumor

- Radiation-induced tumor
  - Risk: 2.4/100 patients-years
    Increases with time (median 9.6 years)
  - Lung, œsophagus, stomach
  - Lung: inside or edge of irradiated area







Radiation-induced thoracic disease
Unusual findings

- **Lung - bronchi**
  - Organizing pneumonia
  - Necrosis/fistula
  - Bronchial thickening/stenosis
  - Eosinophilic pneumonia
- **Pleura**
  - Pneumothorax
  - Thickening
  - Mesothelioma
- **Esophagus**
  - Dysmotility
  - Ulceration
  - Stricture/perforation/fistula
- **Mediastinum**
  - Thymic cyst
  - Fibrosing mediastinitis
  - Nerve injury
- **Lymph nodes**
  - Calcifications
- **Vessels**
  - Stenosis/occlusion > pseudoaneurysm
  - Dissection
  - Calcifications
- **Heart**
  - Coronary artery disease
  - Pericarditis
  - Cardiomyopathy
  - Valvular disease
  - Conduction abnormalities
- **Liver**
  - Focal hepatitis
  - Atrophic liver changes
- **Chest wall**
  - Breast carcinoma
  - Sarcoma/osteochondroma
  - Oedema, calcifications, Skin thickening
  - Osteoradionecrosis
  - Fracture

Mesurolle RadioGraphics 2000;20:67
Benveniste RadioGraphics 2019;39:344
Febbo RadioGraphics 2018;38;1312

Radiation-induced thoracic disease

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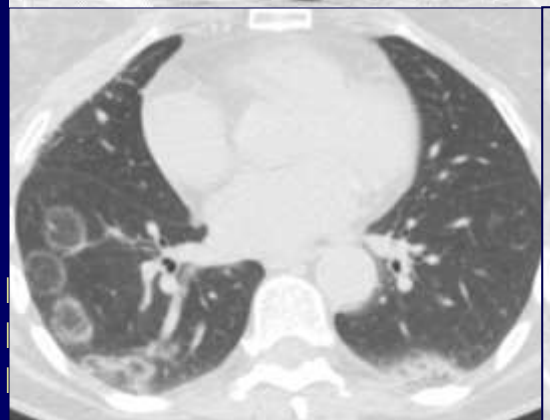

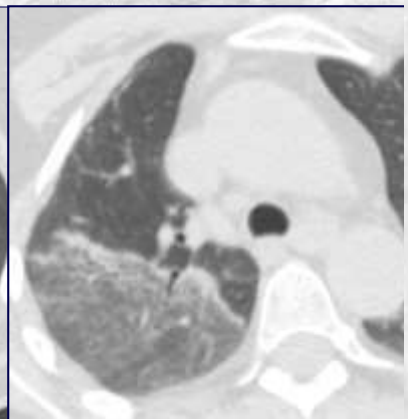

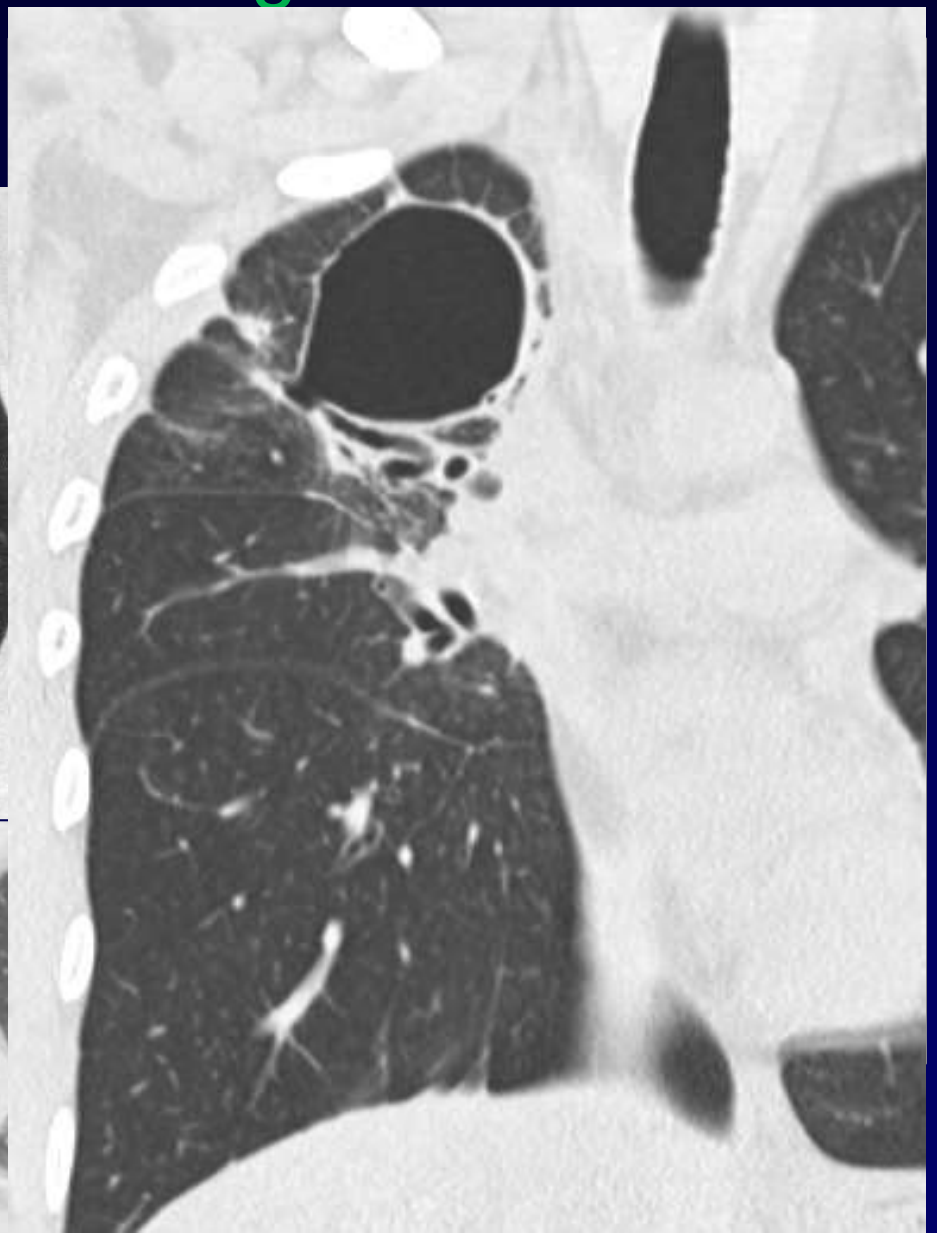

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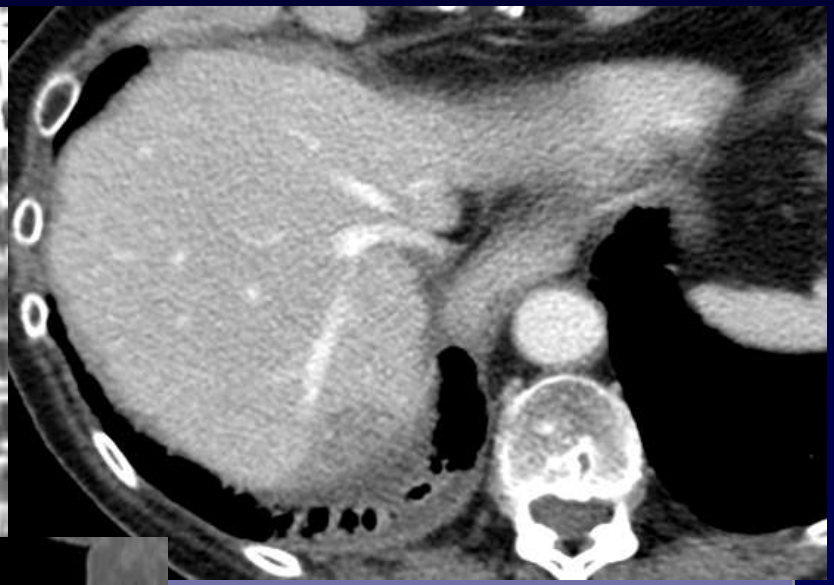

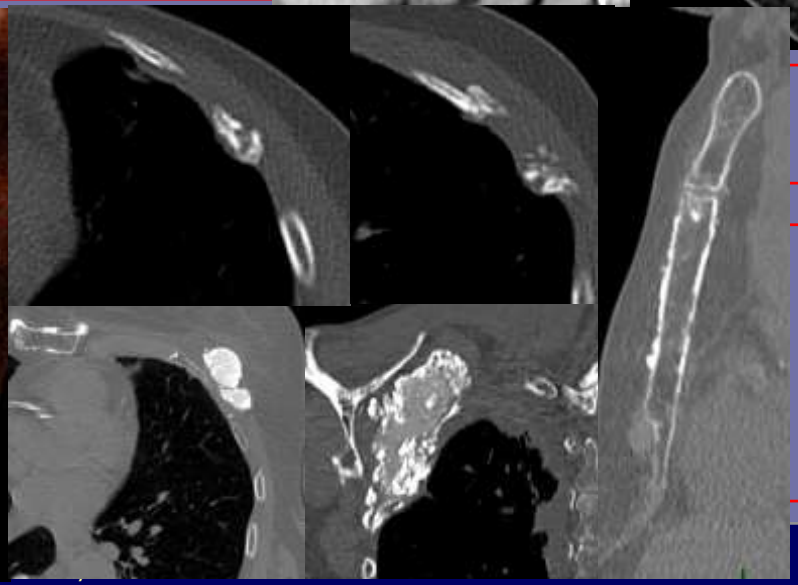

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- Atrophic liver changes

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Benveniste RadioGraphics 2019;39:344
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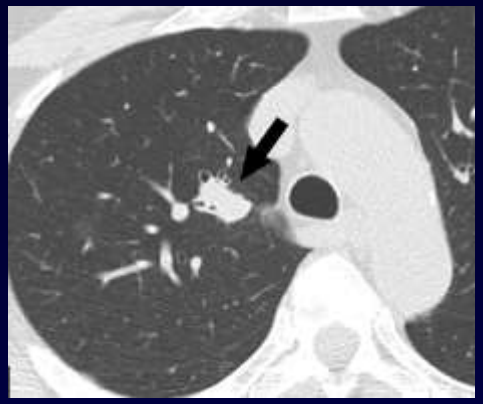


Follow-up after SABR
High-risk features

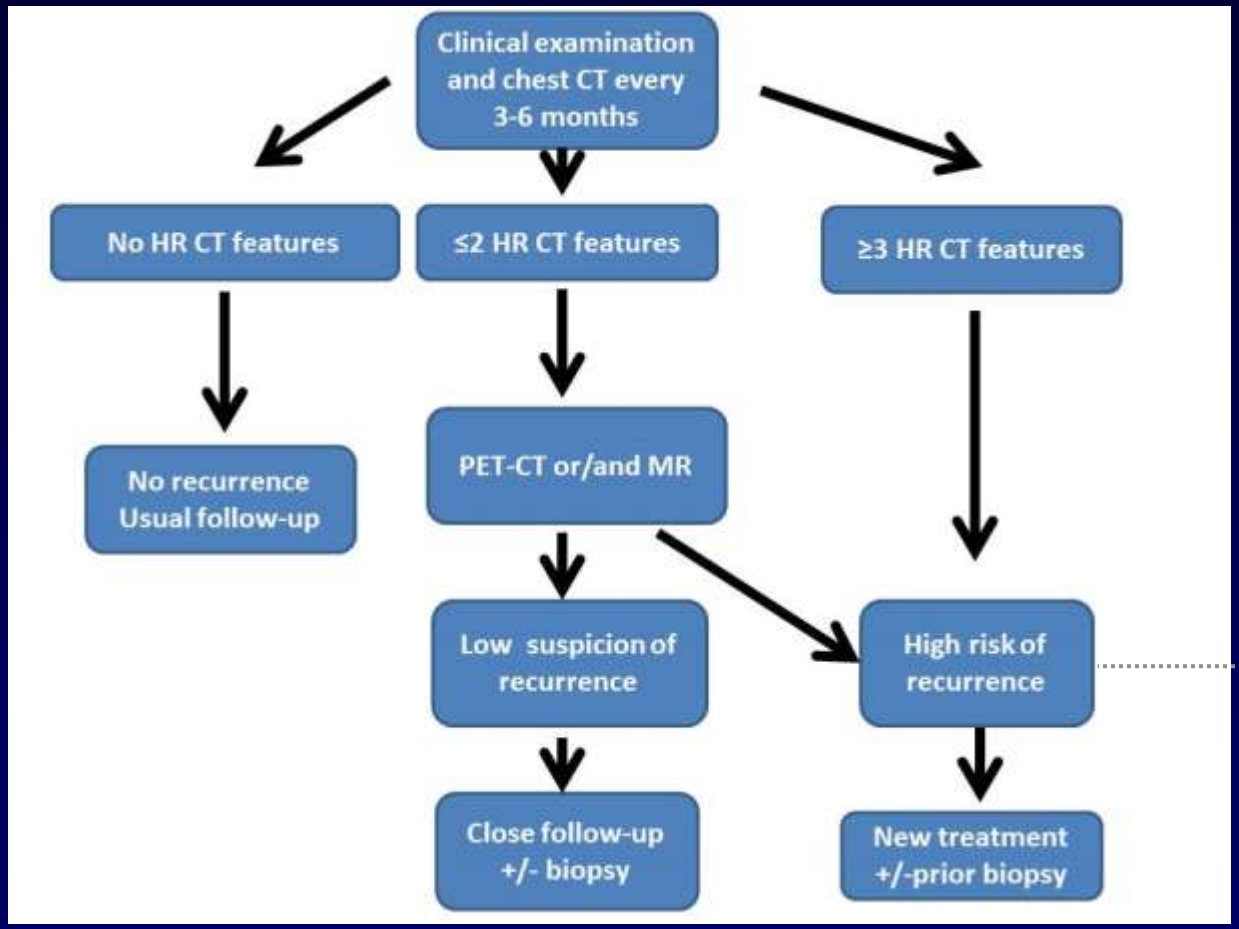
RECIST : 71% FP and 28% PPV

Dunlap Int J Radiat Oncol Biol Phys 2012;84:1071

- Enlarging opacity at the SRBT site
- Sequential enlarging opacity
- Loss of linear margin
- Convex bulging margin
- Disappearance of air-bronchogram
- Enlarging opacity without air bronchogram particularly >12 months
- Cranio-caudal growth > 5 mm and ≥ 20%

Huang Radiother Oncol 2012;102:335-42
Huang Radiother Oncol 2013;109:51-7
Febbo RadioGraphics 2018;38:1312-36

Follow-up after SABR
High-risk features



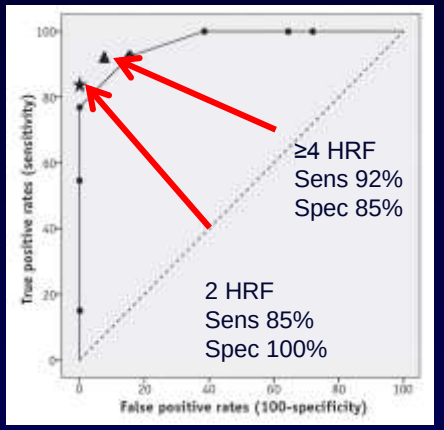
Vansteenkiste J Ann Oncol 2014;25:1462-74
Ghaye Diagn Interv Imaging 2016;97:1037-52
Febbo RadioGraphics 2018;38;1312-36

Follow-up after SABR
High-risk features

Table 2 Sensitivity and specificity of 7 high-risk CT features reported by Huang et al (21, 22) and 2 additionally investigated HRFs

High-risk CT feature for local recurrence	Sensitivity (%)	Specificity (%)	*P* value
Enlarging opacity (≥5 mm and ≥20%)	100	31	.035
Sequential enlarging opacity	62	77	.033
Enlarging opacity after 12 months	92	50	.013
Bulging margin	85	100	<.001
Linear margin disappearance	85	100	<.001
Loss of air bronchogram	15	100	.105
Craniocaudal growth (≥5 mm and ≥20%)	100	50	.001
Unilateral pleural effusion	31	96	.035
Relative growth	85	65	.001

Abbreviations: CT = computed tomography; HRF = high-risk feature.

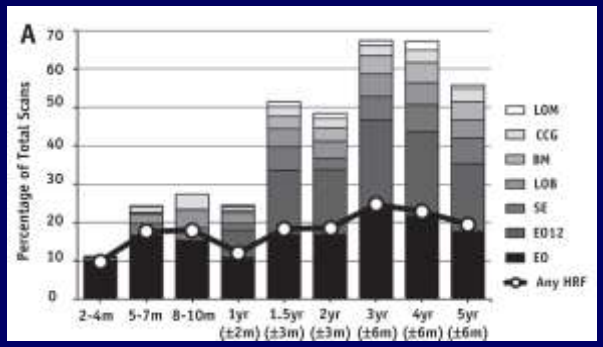


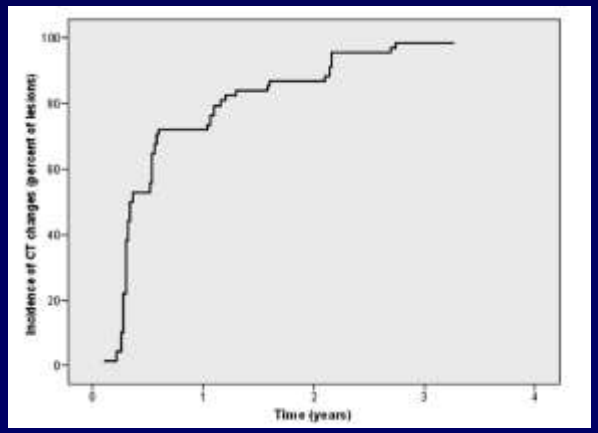
13 pts with local recurrence *vs.* 26 non recurrence

Peulen Int J Radiat Oncol Biol Phys 2016;96:134-41

88 patients without local recurrence
50% have HRF
≥ 3 HRF in 25%
increased rate of FU CT, (PET and biopsy)
large interreader variability

Ronden Int J Radiat Oncol Biol Phys 2018;100:115-21





Dahele J Thorac Oncol 2011;6:1221-8

Follow-up after SABR

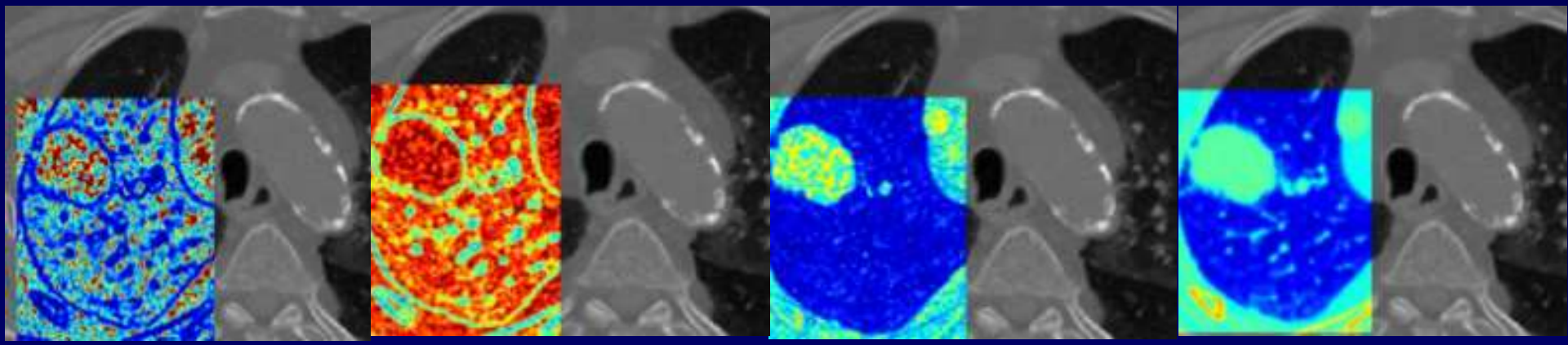
Follow-up after SABR
Radiomics

Imaging features from pre-treatment or post-treatment CT are associated with clinical outcomes in NSCLC treated with SABR[1,2]

[3]

Modèle à 5 paramètres							
Paramètre 1	**Paramètre 2**	**Paramètre 3**	**Paramètre 4**	**Paramètre 5**	**Se (%)**	**Sp (%)**	**Précision**
Diff Entropy	Sum Average	SRE	GLN	16	100	94,3	0,94
Entropy	Sum Average	SRE	GLN	16	100	94,3	0,94
Homogeneity	Sum Average	SRE	GLN	16	100	94,3	0,94
Inv Diff Mom	Sum Average	SRE	GLN	16	100	94,3	0,94
Sum Average	Sum Entropy	SRE	GLN	16	100	94,3	0,94
Sum Average	GLN	RP	Roundness	28	100	94,3	0,94

Seuls les modèles avec une Précision supérieure à celle des modèles à 4 paramètres sont rapportés ici.



[1]Li Med Phys 2017;44:4341-4349
[2]Mattonen SA Int J Radiat Oncol Biol Phys 2016;94:1121-8
[3]Seabra and Ghaye, ECR 2018

Conclusion

- Any thoracic tissue exposed to radiations can show radiation injury
- RILD :
  - Early and late features (reference point)
  - Confinement to the fields of radiation
  - Non-conformity to anatomic boundaries
- RT refinements : modified conventional, mass-like and scar-like patterns
- Knowledge of the treatment planning aids in the interpretation
- Long-term follow-up should be further refined (CT, PET-CT, MRI and PET-MRI)

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