Lung SBRT

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Primary NSCLC

Early-stage NSCLC

Typically, T1 (0-3 cm) and T2 (3-5 cm) N0 M0

Standard for inoperable patients

According to the operability risk stratification

Optional for operable patients

Patients refusing surgery after a multidisciplinary consultation with surgeon and radiation oncologist

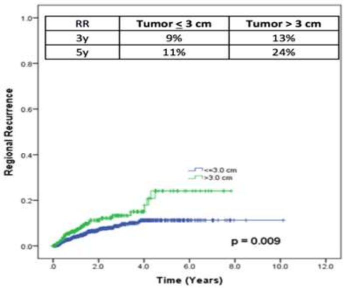
- Risk of understaging in unforeseen N1-2 tumors
- Risk of undertreatment if risk factors: T > 4 cm, pN1-2, by omitting adjuvant Targeted Therapy or perioperative chemo-IO

Lung metastases

See SBRT for oligometastatic diseases

OPERABILITY RISK STRATIFICATION [1]

Lung function	CPET – VO2 max	Operability risk	Options
PreopFEV1>80% PreopDLCO>80%	-	LOW	SURGERY
PreopFEV1<80% and/or PreopDLCO<80%	>20ml/kg/min	LOW	SURGERY
	10-20ml/kg/min	MODERATE	Multidisciplinary discussion
	<10ml/kg/min	HIGH	SBRT



Indication | Motion | Simulation | Delineation | Planning | IGRT | Outcome

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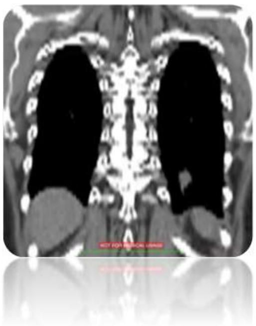
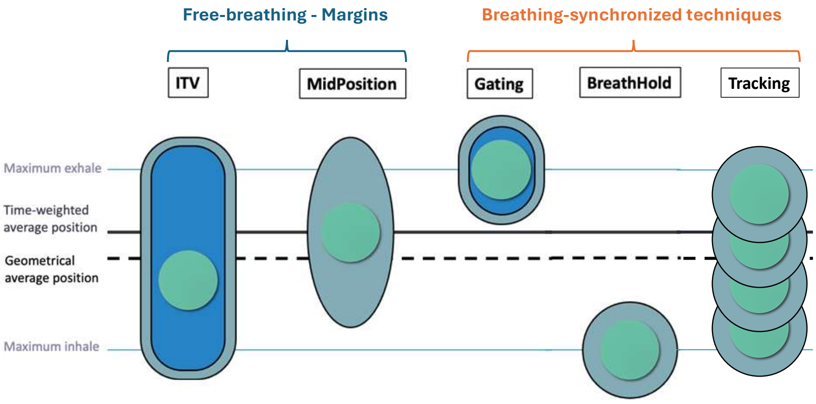
Motion managment





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CT Simulation

Reproductible positioning

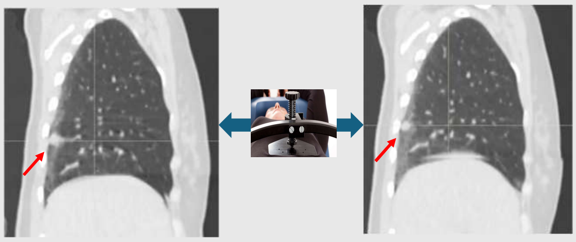
- Stereotactic body frame – vacuum bag – thoracic mask
- Abdominal compression in selected patients

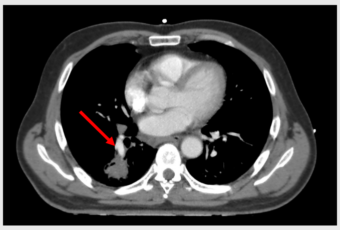
CT acquisition

- 4D-CT for ITV, MidP, respiratory gating and real-time tracking
- Deep-inspiration CT for DIBH
- 1-2 mm slice thickness, from Mandible to below diaphragms

IV contrast agent

- Not required for most (peripheral) tumors
- Potentially useful for centrally-located tumors





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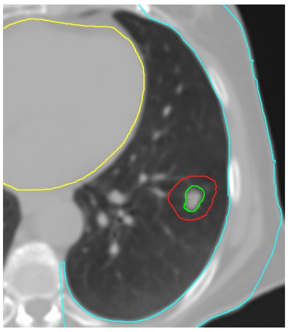
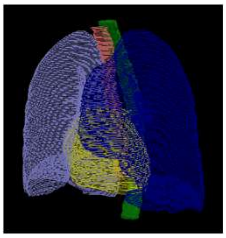
Delineation for lung SBRT

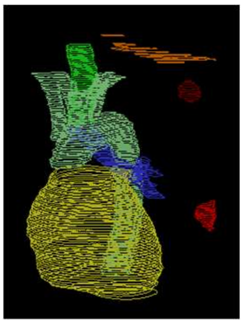
GTV: lung window
No CTV: dose gradient
PTV: according to motion strategy

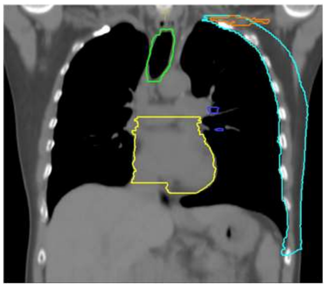




Specific OARs:
+ Great vessels
+ Trachea
+ Proximal bronchial tree
+ Thoracic wall
+ Brachial plexis (UL)

Standard OARs:
heart, spinal cord, lungs, oesophagus





Atlases and delineation guidelines:
Br. plexus: Kong et al, IJROBP 2014
Heart: Feng et al, IJROBP 2011
PBT: De Ruysscher et al, JCO 2010
Thoracic wall: Woody et al, IJROBP 2012

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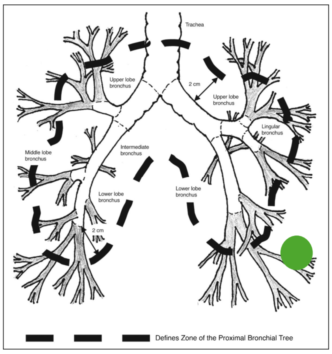
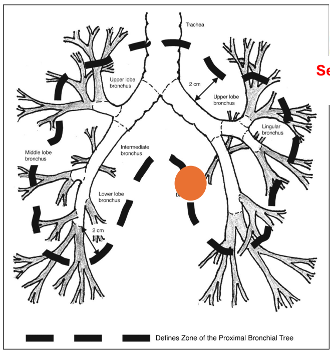
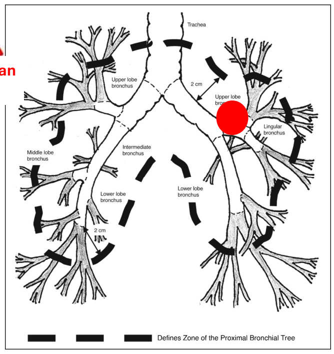
Dose prescription

PERIPHERAL Outside no-fly zone	CENTRAL Within no-fly zone	ULTRA-CENTRAL Abutting PBT, oeso, mediastinum





Serial organ ahead



3x18 Gy – 4x12 Gy – 5x11 Gy
$D_{95\%} = D_{prescribed}$
D_{max}: 125-150% (within GTV)

8x7.5 Gy
$D_{95\%} = D_{prescribed}$
D_{max} < 120%, no endobronchial tumor
OARs constraints prioritized over PTV

8x7.5 Gy – 60 Gy in 10, 12 or 15#
$D_{95\%} = D_{prescribed}$
D_{max} < 120%, no endobronchial tumor
OARs constraints prioritized over PTV

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Dose constraints

	3# RTOG 0618, UK 2022	4# RTOG 0915, UK 2022	5# RTOG 0813, UK 2022	8/10# UK 2022, Sunset	12# Guilani 2018	15#
Spinal canal	$D_{0.035cc}$ < 20.3 Gy	$D_{0.03(cc}$ < 26 Gy $V_{20.8Gy}$ < 0.35 cc	$D_{0.03(cc}$ < 25.3 Gy $V_{22.5Gy}$ < 0.25 cc	$D_{0.035cc}$ < 32 Gy	D_{max} < 37.8 Gy	D_{max} < 39.5 Gy
Lungs - GTV	V_{20Gy} < 15% MLD < 8 Gy	V_{20Gy} < 15% MLD < 8 Gy	V_{20Gy} < 15% MLD < 8 Gy	V_{20Gy} < 15% MLD < 8 Gy	MLD < 12 Gy	MLD < 14 Gy
Trachea/PBT	$D_{0.1cc}$ < 30 Gy	D_{max} < 34.8 Gy $V_{15.6Gy}$ < 4 cc	$D_{0.1cc}$ < 38 Gy V_{18Gy} < 4 cc	$D_{0.1cc}$ < 40 Gy	D_{max} < 59 Gy $D_{0.5cc}$ < 52 Gy	D_{max} < 66 Gy D_{10cc} < 62 Gy
Brachial plexus	$D_{0.1cc}$ < 24 Gy	$D_{0.1cc}$ < 27.2 Gy $V_{23.6Gy}$ < 3 cc	$D_{0.1cc}$ < 32 Gy	$D_{0.1cc}$ < 39 Gy	-	D_{max} < 50 Gy
Heart	$D_{0.1cc}$ < 30 Gy	D_{max} < 34 Gy V_{28Gy} < 15 cc	$D_{0.1cc}$ < 38 Gy V_{32Gy} < 15 cc	$D_{0.1cc}$ < 46 Gy	D_{15cc} < 38.2 Gy	D_{max} < 66 Gy D_{10cc} < 62 Gy
Oesophagus	D_{max} < 27 Gy	D_{max} < 30 Gy $V_{18.8Gy}$ < 5cc	D_{max} < 35 Gy $V_{27.5Gy}$ < 5 cc	D_{max} < 40 Gy	D_{max} < 48 Gy D_{5cc} < 21.6 Gy	D_{max} < 50.5 Gy D_{5cc} < 48 Gy
Great Vessels	$D_{0.1cc}$ < 45 Gy V_{39Gy} < 10 cc	D_{max} < 49 Gy V_{43Gy} < 10 cc	$D_{0.1cc}$ < 53 Gy V_{47Gy} < 10 cc	$D_{0.1cc}$ < 65 Gy	D_{max} < 62.9 Gy D_{10cc} < 55.7 Gy	D_{max} < 64 Gy D_{5cc} < 60 Gy
Thoracic wall	$V_{27.3Gy}$ < 2 cc	V_{30Gy} < 30 cc V_{60Gy} < 1.4 cc	V_{37Gy} < 30 cc	-	-	-
Skin	$D_{0.1cc}$ < 33 Gy D_{10cc} < 30 Gy	D_{max} < 32 Gy V_{30Gy} < 10 cc	$D_{0.1cc}$ < 39.5 Gy D_{10cc} < 36.5 Gy	$D_{0.1cc}$ < 48 Gy D_{10cc} < 44 Gy	-	-

RISK-ADAPTED DOSE PRESCRIPTION

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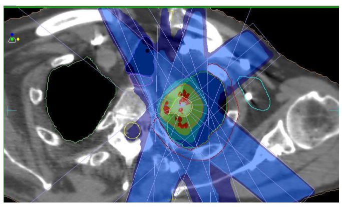
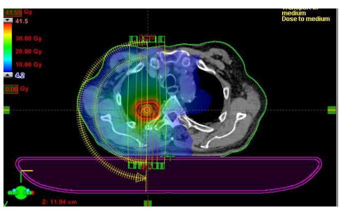
Treatment Planning





Equipment
- LINAC with 3D imaging mandatory
- MLC < 10mm, 4D-CBCT or real-time imaging, 6D-coach, SGRT recommended
- 6 to 10 MeV

Dose prescription and planning
- Risk-adapted dose prescription
- High conformal RT: IMRT, Helical IMRT, VMAT, conformal arc…
- D95% = $D_{prescribed}$
- D_{max} according to central (<120%) vs peripheral (120-150%), within the GTV
- Dose calculation with algo type B or C

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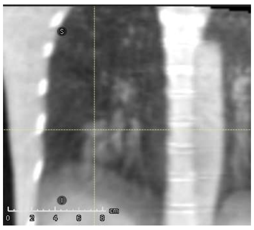
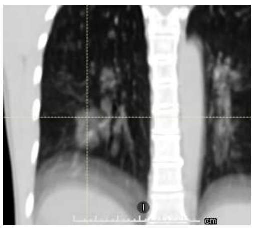
IGRT

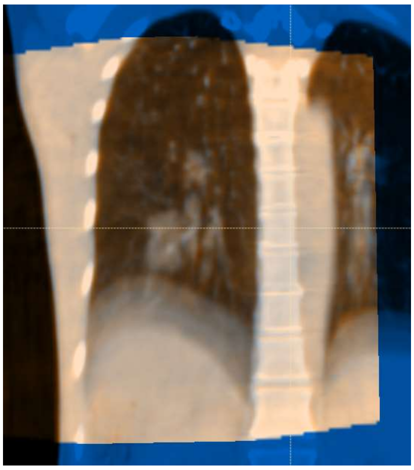
Planning: average 4D-CT

± SGRT – fiducial – real-time imaging…

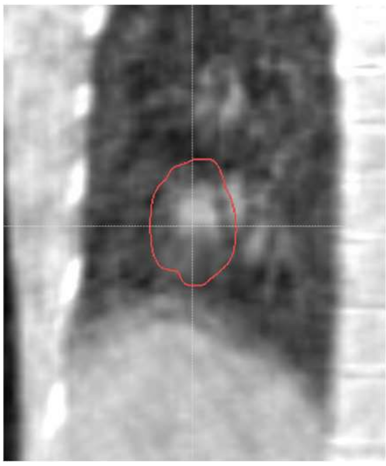




LINAC: 3D or average 4D-CBCT



FUSION



4D-CBCT

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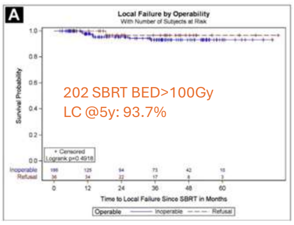
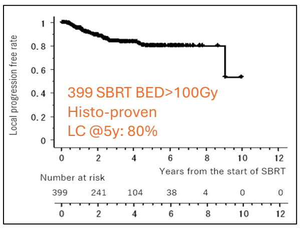
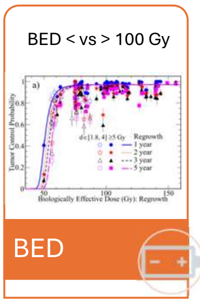
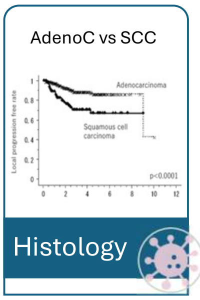
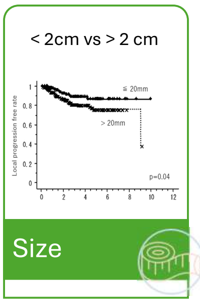
Results: local control

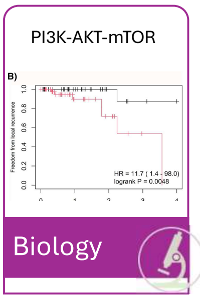












Factors influencing local control rates

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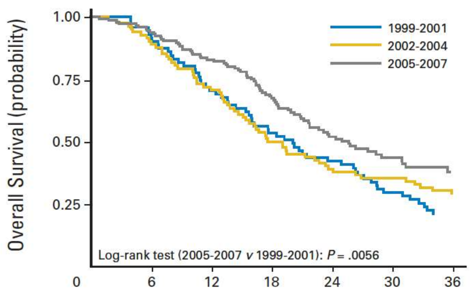
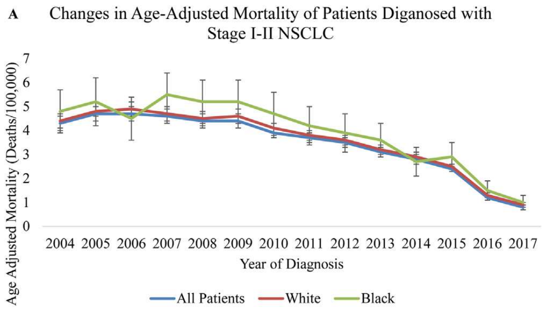
Results: survival benefit

The Netherlands – national registry



USA – SEER



The use of lung SBRT in frail populations significantly reduces cancer-related death @ population level

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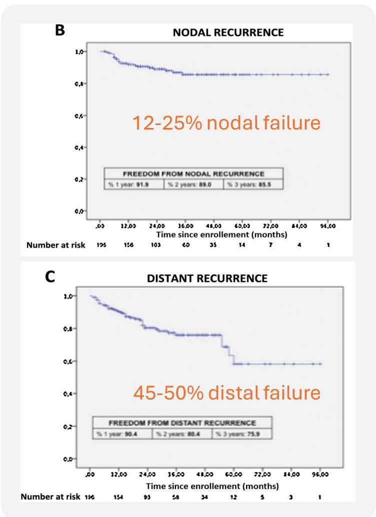
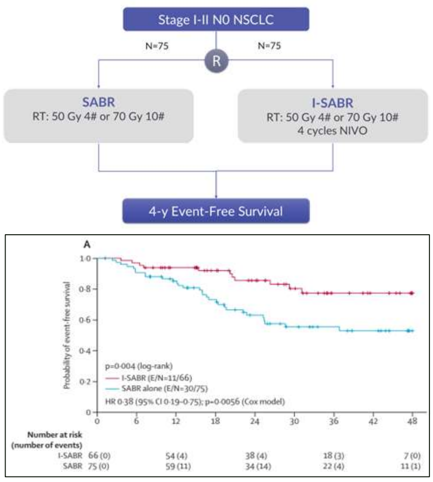
Results: what's next?



IO ❯

I-SABR phase 2 trial



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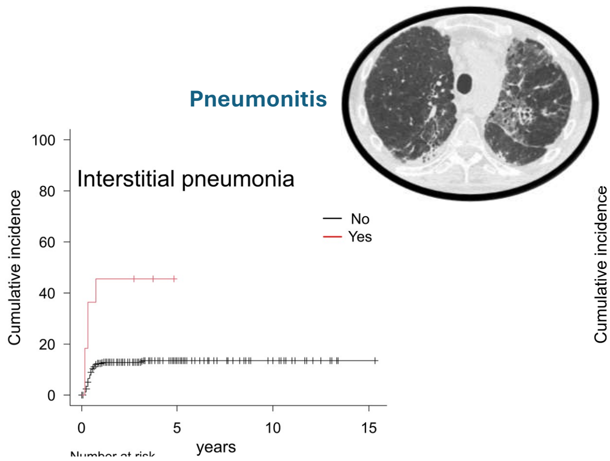
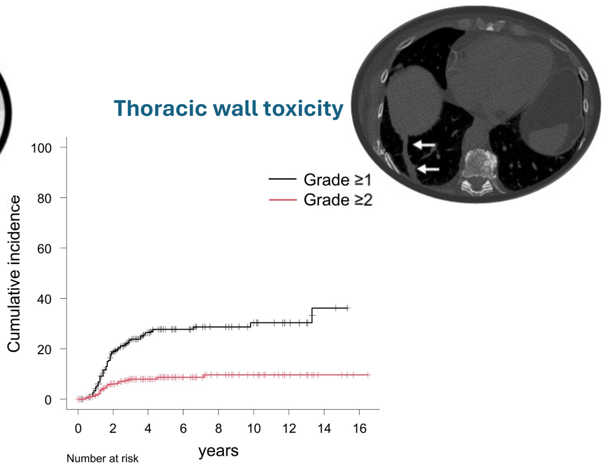
Toxicity in peripheral lung SBRT





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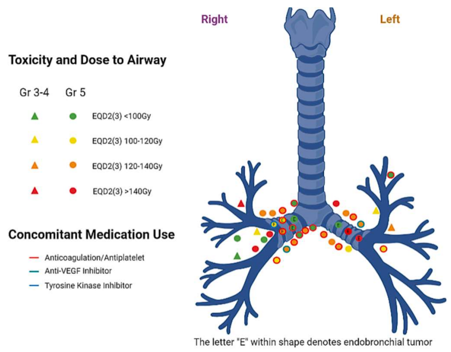
Toxicity in central lung SBRT



<u>Grade 5 toxicity</u>

Mostly fatal hemoptysis

<u>Risk factors</u>:

- anticoagulant
- Lung fibrosis
- Targeted therapy(anti-VEGF)
- Endobronchial tumor
- Hilar tumor
- D_{max}>100 Gy (EQD2) to main and intermediate bronchus

Toxicities	Grade 3-4	Grade 5
HILUS trial (8x7.5 Gy)	15%	13%
Systematic review	6%	4%
SUNSET trial (8x7.5 Gy)*	3.3%	3.3%

*no endobronchial tumor, Dmax < 120 %, OARs prioritised

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Toxicity in central lung SBRT

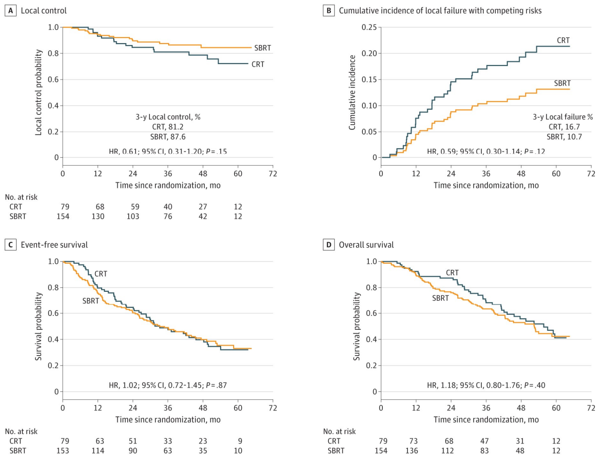
LUSTRE Phase 3 Randomized Trial

- Multicenter RCT (16 Canadian centers)
- n = 233 (2:1)
- SBRT: 48 Gy/4# (peripheral) or 60 Gy/8# (central) **VS** CRT: 60 Gy/15#

Table. Worst Toxic Effects By Grade and Tumor Location

Toxic effect	No. (%) SBRT	CRT
Grade 3-5 central tumors only		
Total, No.	45	19
Long-term toxic effects (>3-36 mo)		
Grade 3	5 (11)	0
Grade 4	0	1 (5)
Grade 5	1 (2)	0

Abbreviations: CRT, hypofractionated conventional radiotherapy; SBRT, stereotactic body radiotherapy.



Hypofractionated RT is a viable alternative to SBRT in challenging case

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Take-home Messages

- **SBRT is the standard of care** for inoperable early-stage NSCLC and a validated alternative for operable patients who refuse surgery
- **Accurate motion management** is crucial for treatment safety and efficacy.
- **Precise delineation and planning**, including risk-adapted dose prescriptions and strict OAR constraints, ensure an optimal balance between tumor control and toxicity.
- **Excellent local control (>90%) with BED >100 Gy**, although regional and distant failures remain common.
- **Toxicity varies by location**: central and ultra-central tumors require greater caution due to higher risks, especially fatal hemoptysis. OAR dose constraints should be prioritized over PTV coverage
- **Futures directions**: integration of SBRT with immunotherapy (e.g., I-SABR) and improved systemic control strategies.

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Guidelines

- Guckenberger et al. ESTRO ACROP consensus guideline on implementation and practice of stereotactic body radiotherapy for peripherally located early-stage non-small cell lung cancer. Radiother Oncol 2017;124:11-17
- Peeters et al. Selective mediastinal node irradiation in non-small cell lung cancer in the IMRT/VMAT era: how to use E(B)US-NA information in addition to PET-CT for delineation? Radiother Oncol 2016;120(2):273-8.
- Hanna et al. UK consensus on normal tissue dose constraints for stereotactic radiotherapy SABR dose constraints. Clin Oncol (R Coll Radiol.) 2018;30(1):5-14
- Milo et al. Delineation of whole heart and substructures in thoracic radiation therapy: national guidelines and contouring atlas by the Danish Multidisciplinary Cancer Groups. Radiothérapie Oncol 2020; 150:121-127
- Kong et al. Consideration of dose limits for organs at risk of thoracic radiotherapy: atlas for lung, proximal bronchial tree, esophagus, spinal cord, ribs, and brachial plexus. Int J Radiat Oncol Biol Phys 2011;81:1442-57
- Feng et al. Development and validation of a heart atlas to study cardiac exposure to radiation following treatment for breast cancer. Int J Radiat Oncol Biol Phys. 2011;79:10-18
- https://www.esmo.org/guidelines/lung-and-chest-tumours
- https://www.nccn.org/professionals/physician_gls/
- Postmus et al. Early and locally advanced non-small-cell lung cancer (NSCLC): ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. Ann Oncol 2017; 28 (Supplement 4): iv1–iv21.

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