Motion Management in Lung Radiotherapy

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Learning Objectives

- Describe respiratory-induced organ motion
- Understand why motion management is critical in lung radiotherapy
- Understand the impact of motion on target delineation and treatment delivery
- Compare different motion management strategies
- Learn about practical workflows with motion management.

Lung SBRT

For primary early stage lung cancers

- Standard of care for inoperable early stage NSCLC.
- Local control rates , overall survival of around 90% in operable patients. Similar to lobectomy .

Lung metastasis

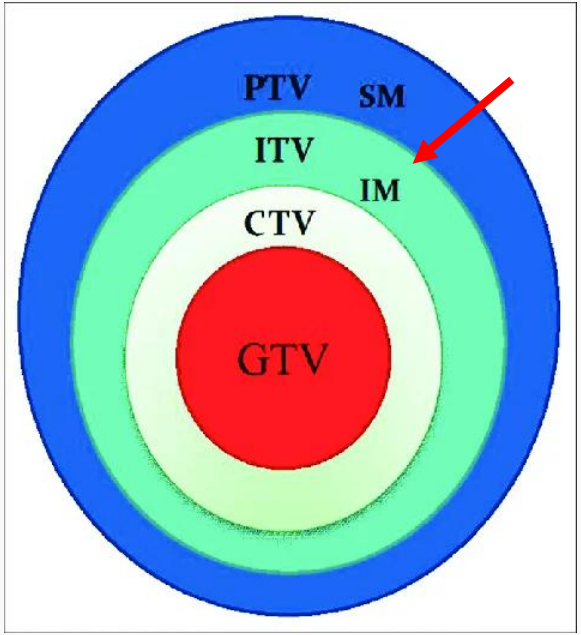
- Oligometastatic cancers
- SBRT + Immunotherapy

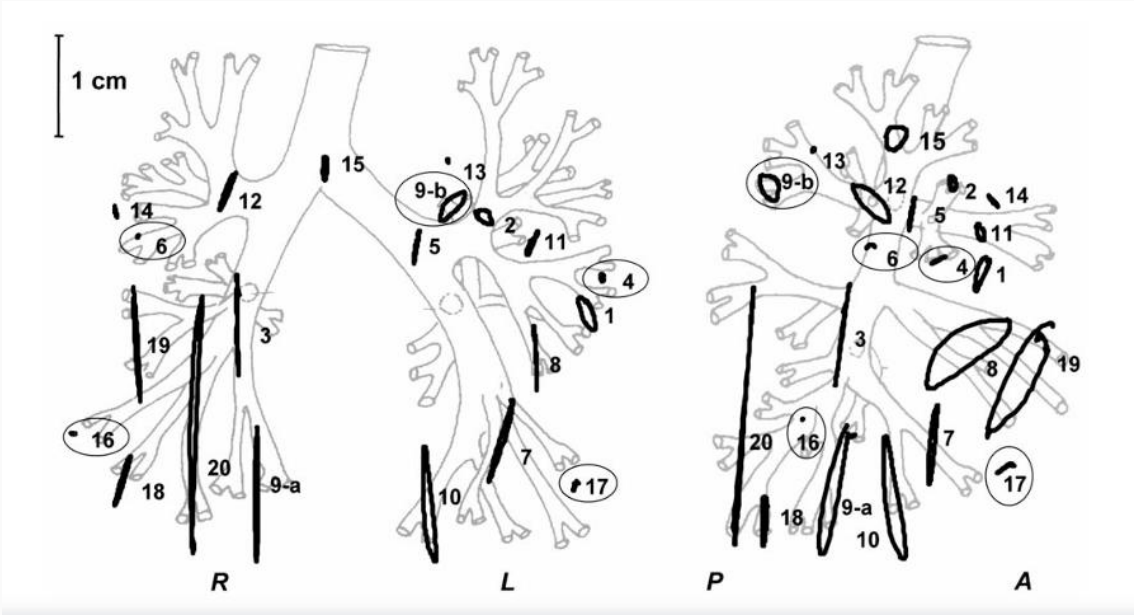
Why Does Motion Matter?

Lung tumors are moving targets.

Consequences of unmanaged motion

- Under-dosing of tumor-> Geographic miss-> Reduced TCP
- Need for larger treatment margins-> Increased dose to organs at risk-> Increased toxicity





Direction	Motion
Superior-Inferior	5–30 mm
Anterior-Posterior	2–10 mm
Mediolateral	1–5 mm

Greatest motion:

- Lower lobe tumors
- Tumors near diaphragm

Least motion:

- Apical lesions
- Chest wall attached tumors

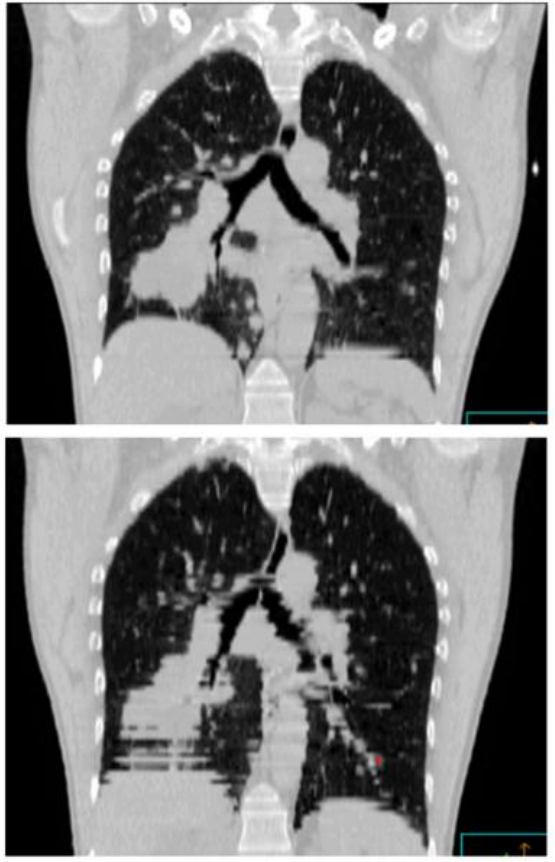
Seppenwoolde Y et al. Int J Radiat Oncol Biol Phys 2002;53:822e834.

Determinants of motion

- Patient related
  - Age, gender
  - Underlying lung disorders- COPD, ILD, Plef.
  - ECOG- muscle fatigability
- Tumor related
  - Tumor location
  - Size
  - Fixity to structures
  - Proximity to heart

A “Snapshot” CT image will not reflect the actual blurring of target and dose- Interplay effect during delivery.

A “slow” CT image will compromise the target clarity during delineation.

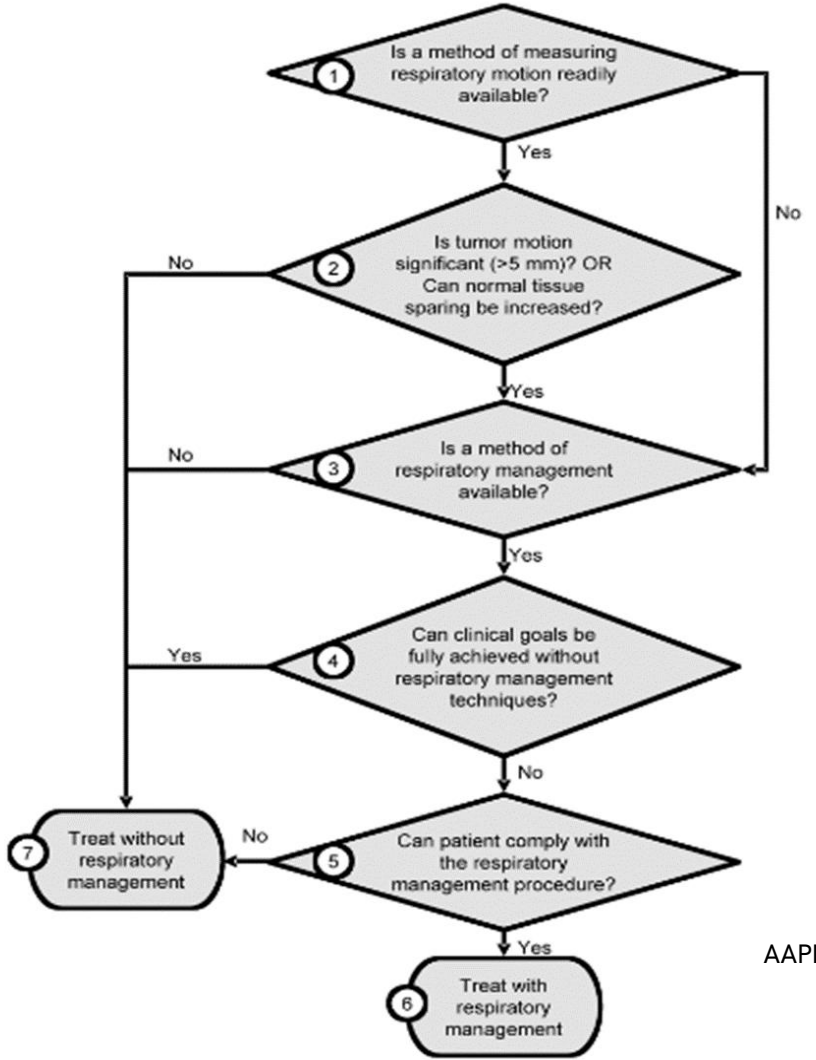


Population based PTV margins to account for the uncertainties may under- or over-treat target

An assessment of 3D tumor motion is essential for treatment planning and delivery- EORTC guidelines 2004

Principles of Motion Management

- Quantify patient- specific motion
- Determine if patient would likely benefit from motion management.
- Decide on the type of motion management
- Quantify residual motion while using the decided method.
- Define margins for the treatment accounting for all uncertainties before RT planning.


1
Is a method of measuring respiratory motion readily available?
Yes
No
2
Is tumor motion significant (>5 mm)? OR Can normal tissue sparing be increased?
No
Yes
3
Is a method of respiratory management available?
No
Yes
4
Can clinical goals be fully achieved without respiratory management techniques?
Yes
No
5
Can patient comply with the respiratory management procedure?
No
7
Treat without respiratory management
Yes
6
Treat with respiratory management

AAPM TG 76

Quantify patient- specific motion

4D CT - ideal

Fluoroscopy- Quick/ available.

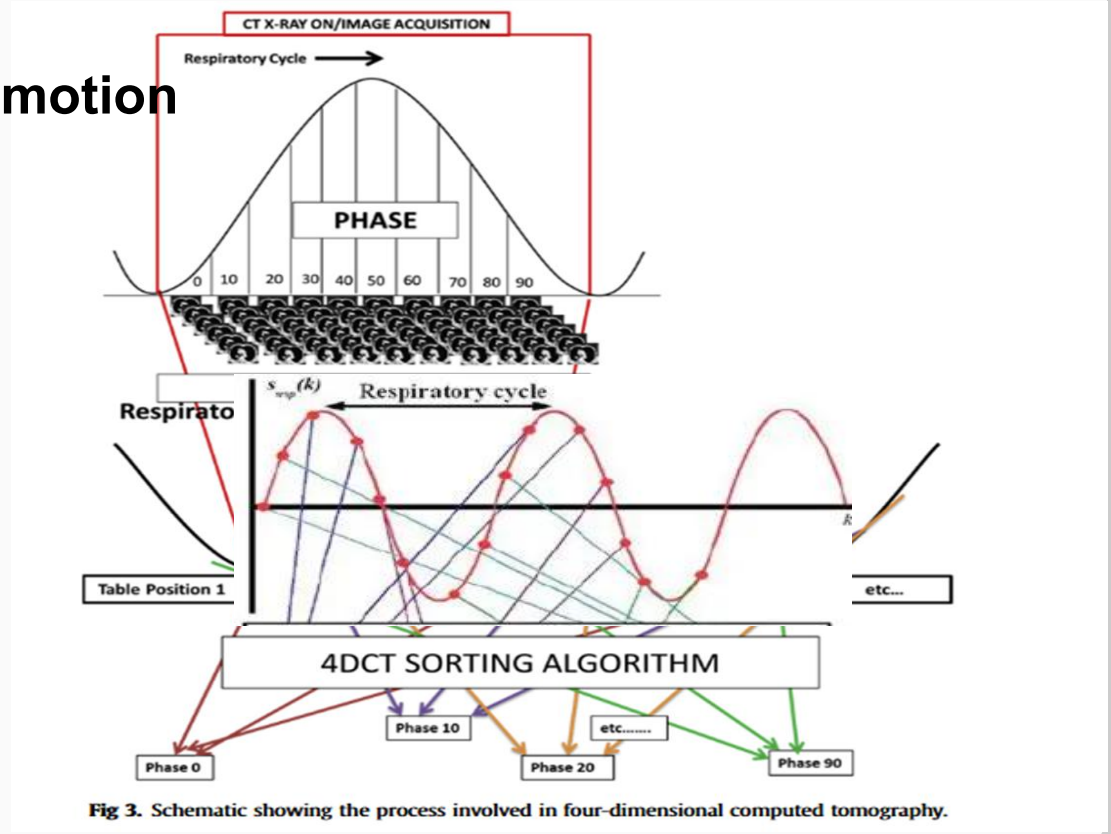


Fig 3. Schematic showing the process involved in four-dimensional computed tomography.

4DCT

Quantifies respiratory motion

Patient-specific margins

Widely available

Essential for lung SBRT

Basis for choosing options

Limitations

Unreliable in irregular breathing

Reconstruction artifacts

Longer acquisition time

Additional imaging dose

Determine if patient would likely benefit from motion management.

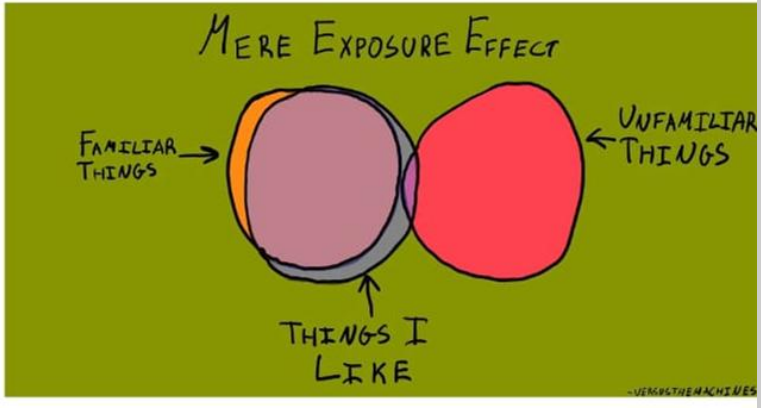
if the magnitude of the motion is very small (<5 mm), the extra effort of using a respiratory management technique is "unwarranted, unless significant normal tissue sparing can be gained with the respiratory management technique" - AAPM TG 76.

Use motion management if:

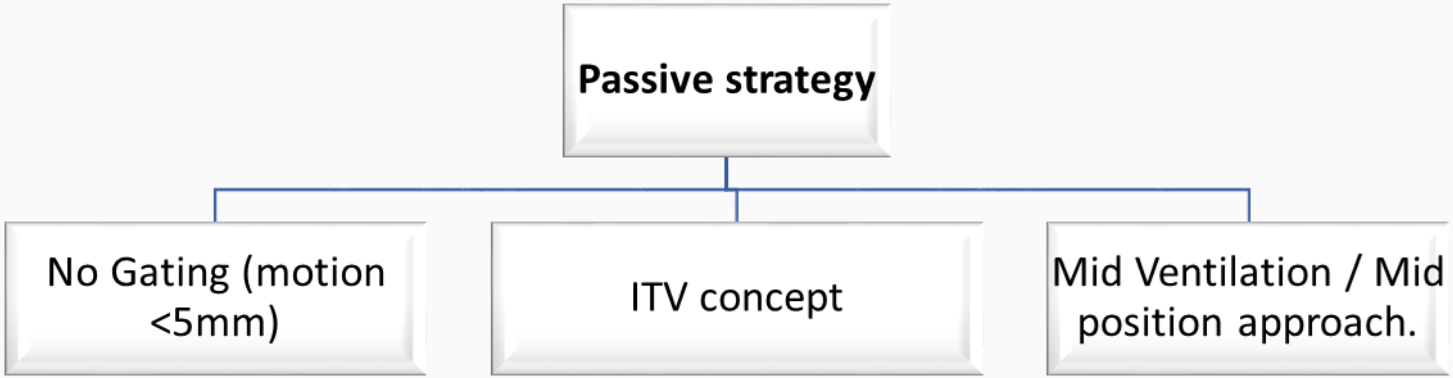
- > 5 mm range of motion in any direction
- Significant normal tissue sparing can be gained (as determined by physician) through the use of a respiration management technique

Decide on the type of motion management

- Largely depends on availability and familiarity!
- Patient’s possible compliance to a selected method
- Dosimetry
- Patient load on machine

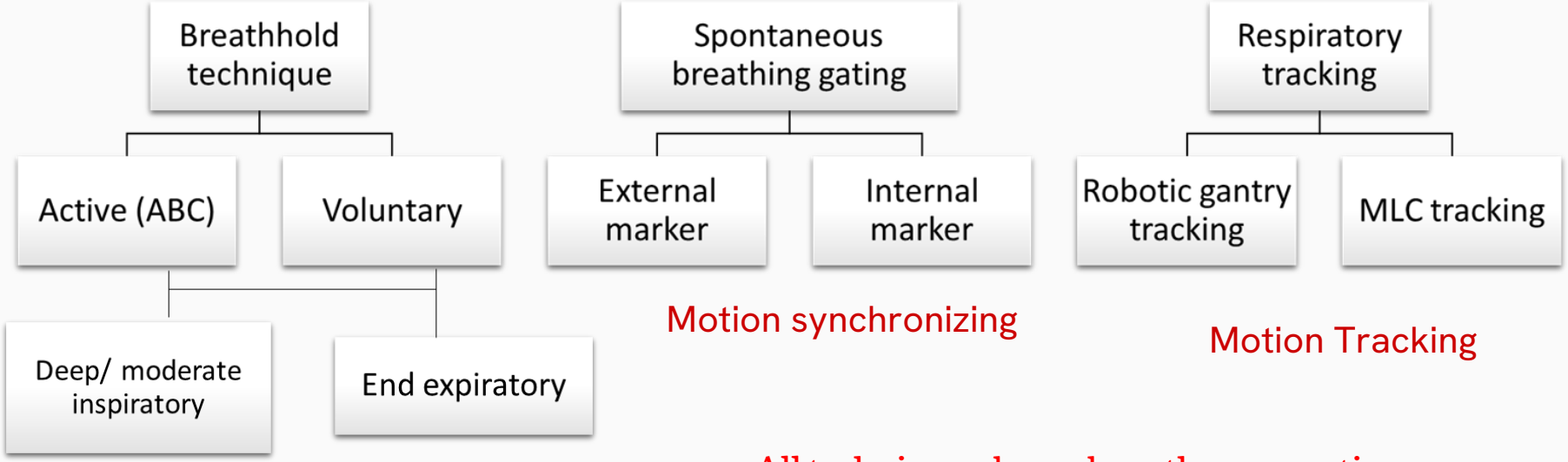


Motion Empassing- Passive Strategies



ADD NOTES

ACTIVE STRATEGY



Motion Mitigating

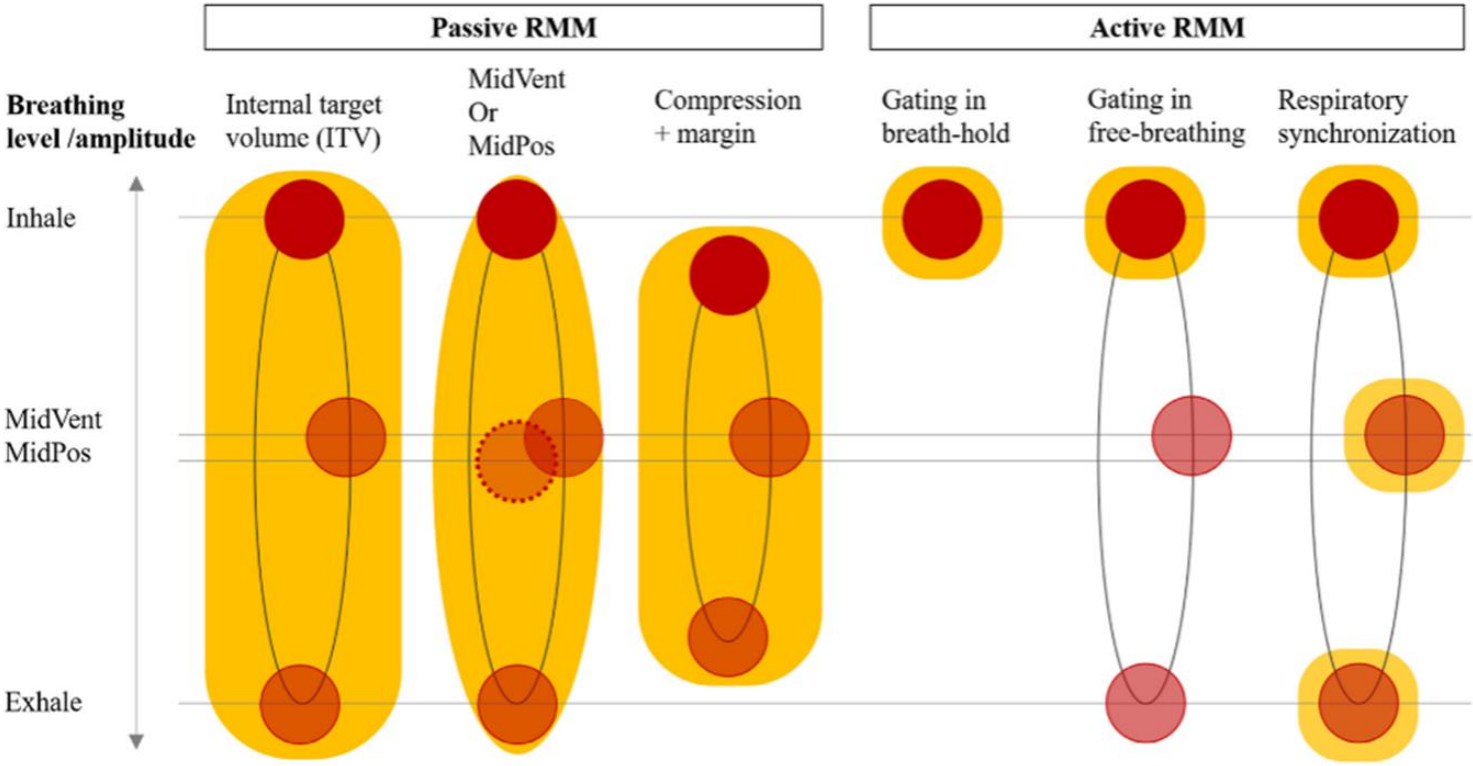
Motion synchronizing

Motion Tracking

All techniques depends on the assumption that patient has a reasonably reproducible breathing pattern

SBRT workflow or equipment items	Mandatory (minimum) requirements
Equipment	
	C-arm linear accelerator with volumetric in-room image guidance
	Respiration correlated 4D-CT
Staff teaching, training and credentialing	
	Written departmental protocols
	Multi-disciplinary project team for SBRT implementation and application
	Structured follow-up for clinical outcome assessment
Patient selection for SBRT	
	Discussion in interdisciplinary tumor board
	Minimum ECOG 3
	Minimum life expectancy of 1 year
Treatment planning	
	3D conformal treatment planning
	Type B algorithms
	Respiration correlated 4D-CT imaging
	ITV based motion management strategy
Dose and fractionation	
	Risk adapted fractionation schemes for peripheral and central tumors, and for tumors with broad chest wall contact
Inter- and intra-fraction image guidance	
	Daily pre-treatment volumetric image-guidance
Follow-up	
	Follow-up according to published guidelines
	FDG-PET imaging in case of suspected local recurrence
Quality assurance	
	Intensified quality assurance (mechanical accuracy of 1.25 mm and a dosimetric accuracy of 3% in a lung phantom inside the treatment field)
	Small field dosimetry detectors for commissioning
	End-to-end testing in a lung phantom
	Quality assurance of in-room image-guidance systems and of the 4D-CT scanner
	Weekly checks of the mechanical accuracy of the delivery system
	Daily quality checks of the alignment of the IGRT system with the MV treatment beam

Guckenberger M 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)



Dhont et al Clinical Oncology 32 (2020) 792-804

Free breathing

Strengths

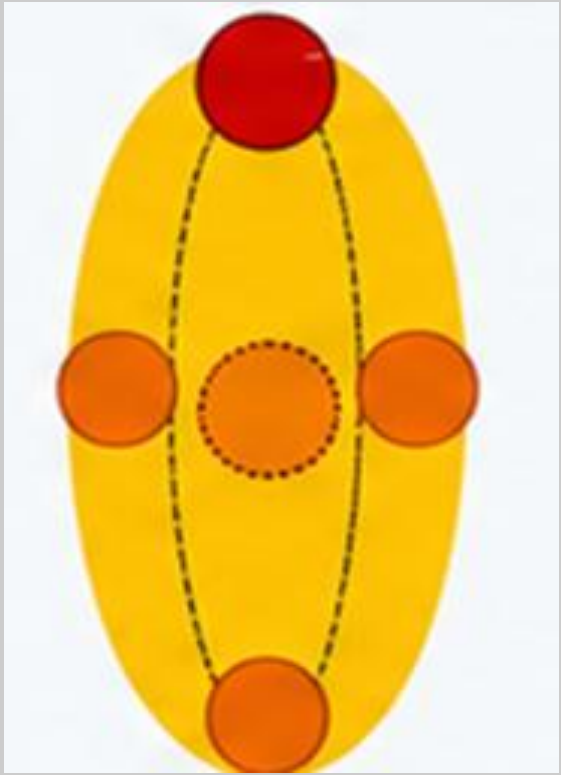
Simple - no technological requirement

Use when < 5mm movement by fluoroscopy/ 4DCT

Limitations

Largest PTV- lowest conformity.

Highest dose to OARs



Strengths

4DCT determined motion envelope for individual

Reduced PTV/ OAR doses

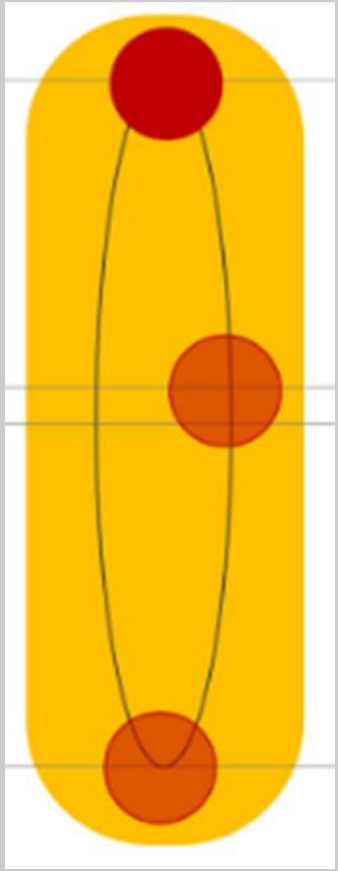
Better conformity

Limitations

Large PTV

4DCT required

ITV based approach



Strengths

Mouthpiece with spirometer

Controlled breath hold at desired level.

Reproducible breath hold

Reduced motion

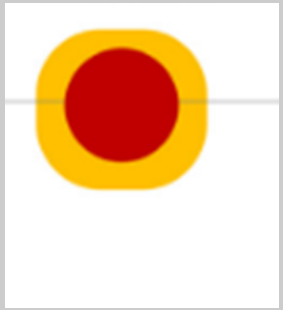
Limitations

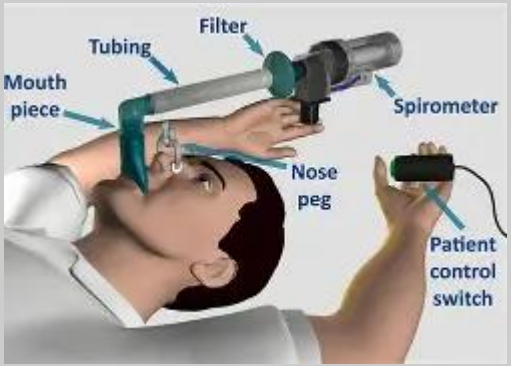
Additional equipment

Patient discomfort

Difficult for pts with poor pulmonary fn

ABC





Voluntary DIBH

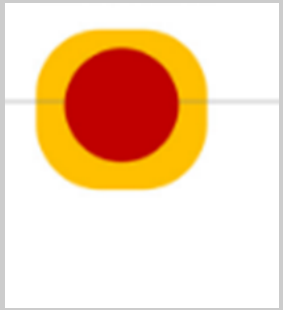
Strengths

Hold at deep or moderate inspiration

Reduced motion- smaller PTV

Good OAR sparing- larger lung volume

Faster Rx than gating



Limitations

Difficult for pts with poor pulmonary fn

Reproducibility may be an issue- mitigated by visual devices

Abdominal Compression

Strengths

Simple, Easy, inexpensive

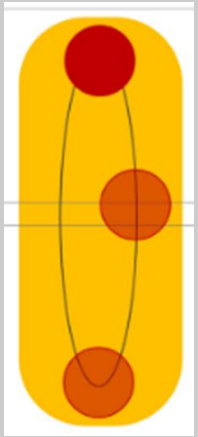
F aster treatment

Moderate Setup margin

Limitations

Variable benefit in OAR sparing

Patient comfort and reproducibility



Respiratory Gating

Strengths

Reduced motion uncertainty

Smaller PTV margins

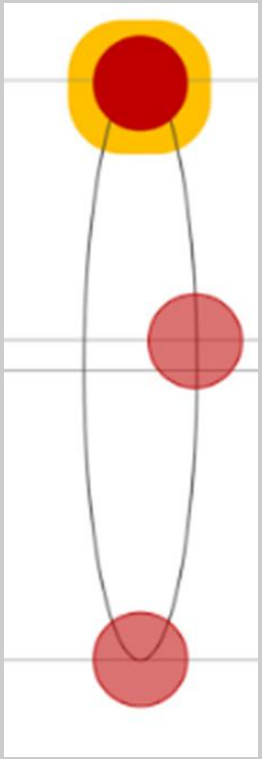
Better normal tissue sparing

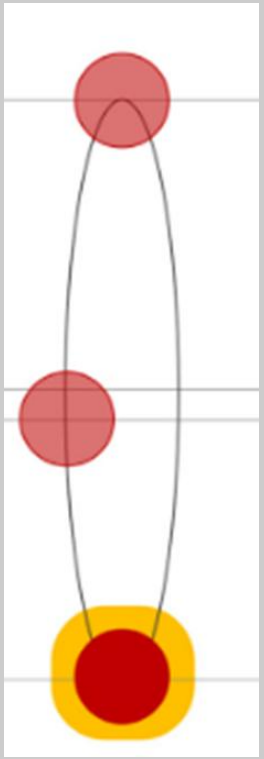
Limitations

Increased treatment time

Complex workflow- Additional QA

Dependence on breathing regularity





Strengths

Smallest margins

Real-time adaptation

Excellent normal tissue sparing

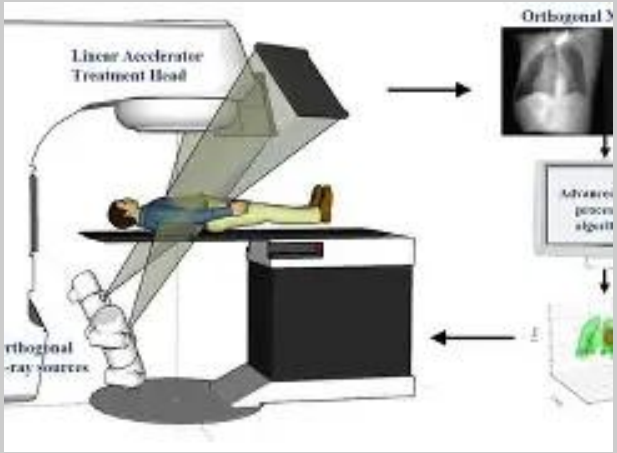
Limitations

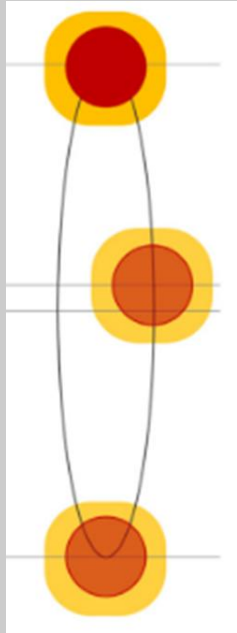
Expensive, Specialized equipment

Fiducial insertion risks

Extensive QA needed

Tracking





Fiducial-based tracking
Dynamic MLC tracking
Robotic tracking

•AAPM TG76- Motion management

• AAPM TG101- SBRT

EORTC recommendations- RadiotherOncol 2017.

•ESTRO ACORP recommendations – RadiotherOncol 2017.

•ASTRO guidelines – PracRadOncol 2017.

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