Motion Management for lung and thoracic cancer

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Scope of presentation

- Introduction
- Review the motion management techniques and basic principles of available motion management techniques
- Advantages and disadvantages
- Motion management technique for lung SBRT in Ramathibodi Hospital
  CyberKnife vs Edge: Based on true story
The results of early stage and locally advanced lung cancer with radiation
Stage I lung cancer

2D/3D RT

High local failure rates after high-dose RT

- Earlier use of 2D-RT planning
- Suboptimal dose of RT
- Geographic miss

Fang LC, 2006
Stage I CA lung

SBRT

High Local control rate ~ 80-100%

Chi et al, 2010

<table>
<thead>
<tr>
<th>Trial</th>
<th>n</th>
<th>Dose</th>
<th>FU</th>
<th>LC %</th>
<th>OS %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyoto</td>
<td>45</td>
<td>12 Gy x 4</td>
<td>32 mo</td>
<td>94</td>
<td>83/72 (3-y)</td>
</tr>
<tr>
<td>Stanford</td>
<td>20</td>
<td>15-30 x 1</td>
<td>18 mo</td>
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<tr>
<td>Scandinavian</td>
<td>57</td>
<td>15 Gy x 3</td>
<td>35 mo</td>
<td>92 (3-y)</td>
<td>60 (3-y)</td>
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<tr>
<td>Indiana</td>
<td>70</td>
<td>20-22 x 3</td>
<td>50 mo</td>
<td>88 (3y)</td>
<td>43 (3-y)</td>
</tr>
<tr>
<td>RTOG 0236</td>
<td>55</td>
<td>20 Gy x 3</td>
<td>34 mo</td>
<td>97</td>
<td>56 (3-y)</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>19-30 x 1</td>
<td>15 mo</td>
<td>68</td>
<td>37 (3-y)</td>
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<tr>
<td>Heidelberg</td>
<td>62</td>
<td>15 Gy x 3</td>
<td>28 mo</td>
<td>88</td>
<td>57 (3-y)</td>
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<tr>
<td>Tohoku</td>
<td>31</td>
<td>15 x 3, 7.5x8</td>
<td>32 mo</td>
<td>78/40</td>
<td>71 (3-y)</td>
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<tr>
<td>VU Univ</td>
<td>206</td>
<td>20 x 3, 12 x 5</td>
<td>12 mo</td>
<td>97</td>
<td>64 (2-y)</td>
</tr>
</tbody>
</table>

- BED: 112.5 -151.2Gy
  - 50Gy/12.5 Gy/fx x 4
  - 54Gy/18 Gy/fx x 3
  - 60Gy/12Gy/fx x 5
- PTV=GTV+3mm
- GTV: 110-140% of prescribe dose
- Volumetric IGRT/Motion management

Chi et al, 2010
LA-NSCLC – Standard vs High dose

RTOG 0617/NCCTG N0628/CALGB 30609

A RANDOMIZED PHASE III COMPARISON OF STANDARD-DOSE (60 Gy) VERSUS HIGH-DOSE (74 Gy) CONFORMAL RADIOTHERAPY WITH CONCURRENT AND CONSOLIDATION CARBOPLATIN/PACLITAXEL IN PATIENTS WITH STAGE IIIA/IIIB NON-SMALL CELL LUNG CANCER

<table>
<thead>
<tr>
<th>Grade ≥3</th>
<th>60 Gy</th>
<th>74 Gy</th>
<th>P Value</th>
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<tbody>
<tr>
<td>Pulmonary</td>
<td>20%</td>
<td>19%</td>
<td>0.71</td>
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<tr>
<td>Pneumonitis</td>
<td>7%</td>
<td>4%</td>
<td>0.25</td>
</tr>
<tr>
<td>Esophagitis</td>
<td>7%</td>
<td>21%</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Any</td>
<td>76%</td>
<td>79%</td>
<td>NS</td>
</tr>
<tr>
<td>Toxicity</td>
<td>N=3</td>
<td>N=8</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Median overall survival: 28.7 months (60 Gy) vs. 20.3 months (74 Gy), p=0.0042

RTOG 0617: Local Tumor Failure

![Graph showing local progression rate over time and comparison between standard (60 Gy) and high dose (74 Gy) treatments. The graph indicates a higher failure rate for the high dose group with a hazard ratio (HR) of 1.37 (0.99, 1.89) and a p-value of 0.0319.]

- Local Progression Rate (%)
  - 0
  - 25
  - 50
  - 75
  - 100
- Months since Randomization
  - 0
  - 3
  - 6
  - 9
  - 12
  - 15
  - 18
- Patients at Risk
  - Standard (60 Gy): 213, 205, 187, 165, 137, 113, 85
  - High dose (74 Gy): 206, 197, 170, 134, 105, 80, 62

Fail  Total
- Standard (60 Gy): 65 213
- High dose (74 Gy): 81 206

HR=1.37 (0.99, 1.89)  p=0.0319
Authors: “heart dose might best explain why patients given 74 Gy did worse than patients given the 60 Gy”
Did increased heart dose in the 74 Gy arm (V50 -11% vs 7%) lead to an increase in intercurrent cardiac death?
Why 74 Gy fail?

• One of hypothesis
  • To meet RT dose constraints, less optimal RT was delivered to the 74 Gy arm patients, leading to poor RT dose distribution and an influence on toxicity and/or tumor control.
How to improve therapeutic ratio?

Need technologies that allow an increased dose to the tumor while sparing healthy tissue will improve the balance between complications and cure.

Radiation dose escalation without increase toxicity.
Advanced radiation therapy

IGRT: Rationale

Set up errors deletion
Organ motion reduction/compensation
Target missing risk

Tumor dose
OAR dose
Intrafraction motion

An important issue in IGRT era

- Motion during a fraction
- Change in instant geometry
- Caused by internal organ motion
  - Respiratory – much research and development
  - Skeletal muscle
  - Cardiac
  - Gastrointestinal
Many sources of error in RT

Respiratory motion is just one potential source of error in radiotherapy.
Lung tumor: Range of motion

- SI- 12 mm on average, up to 50 mm
- Largest tumor motion in lower lung
Summary of motion measurement

- No general patterns of respiration
- Many individual characteristics of breathing—quiet versus deep, chest versus abdominal, healthy versus compromised, etc.
- Many motion variations associated with tumor location and pathology
- No association between surrogate (chest wall or diaphragm) and tumor or normal structure

Lead to distinct individual patterns in displacement, direction, and phase of tumor motion
When to manage respiratory motion?

AAPM Task Group 76: respiratory management techniques should be considered if either of the following conditions occur:

- >5 mm range of motion is observed in any direction; or
- Significant normal tissue sparing as determined by your clinic can be gained using a respiration management technique.

The management of respiratory motion in radiation oncology report of AAPM Task Group 76
Key component of motion management

**Imaging**
- Slow CT
- Breath hold CT
- 4D-CT

**Real-time intervention**
- Abdominal compression
- Breath-hold
- Gating
- Tracking

**Real-time monitoring**
- Optical (RPM, Vision RT)
- Electromagnetic (Calypso)
- Hybrid MRI
- MRI
Motion Management Methods

1. Motion-encompassing methods
2. Breath-hold methods
3. Force shallow breathing with abdominal compression
4. Respiratory gating methods
5. Real-time tumor-tracking methods

All Methods are beneficial in treating moving tumors
Minimal statistical differences in motion management between the techniques

Keall et al: AAPM Task group 76
Motion encompassing method

Conventional CT imaging  

4D CT – showing all possible tumor positions
First routinely available 4D imaging technique for lung tumors
4D imaging using slow CT scan

Serial CT slices

4 seconds per slice

Actual tumor  ‘Slow’ image  Fast CT  ‘Slow’ CT

Lagerwaard 2001
Slow CT scan

• The imaged structures show the full extent of their movement with respiration

• Disadvantages
  • Loss of resolution – delineation errors increase
  • Not recommended for lesion close to mediastinum, chest wall or diaphragm, abdominal tumors

Suggested PET*- long acquisition time
Inhale and exhale breath hold CT scan

- CT scan in inhale and exhale breath hold
- Range of motion of target can be determined after fusion
- Combine inhale and exhale GTV to get ITV

**Advantage**
- Blurring is significantly reduced

**Disadvantages**
- Increase scan time
- Relies on the patient’s ability to hold breath reproducibility
CT Sim with breath hold
4DCT (Respiratory correlated CT)

- A process of obtaining image data sets that images are acquired at each couch position for many respiratory phases.
- Other movements/temporal events (peristalsis, heart beat, organ filling) may or may not be accounted.
- Important to coach patient for periodic breathing as it's important for image sorting.
- Breathing extent is not the tumor motion but motion of the marker.
Patient Training

- The ability to achieve reproducible breathing or breath-hold patterns is a requirement for allowing the patient to proceed to simulation and treatment.
- Prior to start of simulation, the patient should be made familiar with the equipment and its purpose.
- A physicist or trained designee should perform the coaching and evaluation, at least in the initial clinical implementation.
Varian RPM (Real-time positioning management) system
4D image sorting

CT Image Sorting Program

- End-inspiration
- Full respiratory cycle 4 sec
- End-expiration

Mid-exhale
End-exhale
Mid-inhale
End-inhale

10 respiratory ‘bins’ obtained
4DCT

• 4D CT not only reduces motion artifacts, but also gives the tumor/organ motion information
• Irregular respiration will cause artifacts in 4D CT images
• Breathing coaching is always needed
• Radiation exposure from 4DCT is ~ 6 times the dose of a single conventional helical CT scan
• Generation of individualized and usually smaller target volumes derived from 4DCT scans in comparison to standard PTVs justifies this additional radiation exposure
4D-CT - Significant reduction of the mean PTV from 57.7 cc to 40.7 cc (31%) \( (p < 0.001) \), mean lung dose by 17\% \( (p < 0.001) \)
FIGURE 6. Example of missing the target because of intrafraction tumor motion. An IMRT plan was developed for a stage I NSCLC located in the left lower lobe using conventional free-breath CT simulation with uniform PTV margin. The plan was recalculated in 10 breathing phases obtained using 4-D CT. The inferior portion of the CTV (yellow line) moved outside the prescription dose line (red line, 70 Gy) in phases 1 through 4.
Maximum intensity projection (MIP)

Maximum HU over all respiratory phases. e.g. Lung tumor. ITV can be estimated by contouring on MIP in lung tumors. Not applicable for GI RT

Minimum intensity projection (MIN)

Minimum HU over all respiratory phases.

Average intensity projection (AVG)

Average of all HU at a specific location (often leads to blurred image)

Xi, R & O 2009
Caution when using MIP

Caution with MIP’s for tumors adjacent to mediastinum, diaphragm and atelectasis
RPM with breath hold CT
Motion Management Methods

1. Motion-encompassing methods
2. Breath-hold methods
3. Force shallow breathing with abdominal compression
4. Respiratory gating methods
5. Real-time tumor-tracking methods

Keall et al: The management of respiratory motion in radiation oncology report of AAPM Task group 76
Breath hold methods

• Deep-inspiration breath hold (DIBH)

• Active Breathing Control (ABC)

**Spirometer-monitored technique**

Self-held breath hold with respiratory monitor
- RPM
- Optical surface
- Mechanical devices tracking the torso
- Thermal sensors near nostril
- Fluoroscope images of implant fiducials
- Implants transponders
BH : Inspiration vs Expiration

**Inspiration**
- Potential for greater separation between the target and sensitive organs
- Lung volumes are largest and improves lung DVH
- Prefer in thoracic lesion (Lung, breast, mediastinum)

**Expiration**
- More reproducible and stable
- Prefer in abdominal lesion

Heart move away from the chest wall  
DIBH
PROS & CONS of DIBH/ABC

**PROS**
- Supports automated gating
- Guarantee reproducible breath hold

**CONS**
- Time consuming daily patient set up
- May be difficult for patients with claustrophobia, elderly or pulmonary dysfunction
- Disposable mouth pieces replaced daily
PROS & CONS of self-held BH

**PROS**
- Patient respiration is constantly monitored
- Supports automated gating

**CONS**
- Rely heavily on the patient’s ability and perform a reproducible BH
- Stability of internal anatomy during BH: some pts have been observed to have continuous diaphragm motion during BH, even though they believe they are holding their breath
Motion Management Methods

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Keall et al: The management of respiratory motion in radiation oncology report of AAPM Task group 76
Force shallow breathing with abdominal compression

- Motion amplitude of free breathing can be reduced by mechanical abdominal compression
- Recently, it has been shown to be beneficial only for lower lobe tumors and has no effect or a negative effect on middle and upper lobe tumors
- Whereas the intrafractional amplitude of tumor motion can be reduced by abdominal compression, interfraction motion can even be increased
The most significant impact of AC was obtained in patients with lower lobe tumor. The mean reduction of tumor motion amplitude was 3.5 mm ($p = 0.009$) for lower lobe tumors and 0.8 mm ($p = 0.026$) for upper/middle lobe locations. Compression increased motion in 5 cases.

Clinical outcome with or without AC

The impact of abdominal compression on outcome in patients treated with stereotactic body radiotherapy for primary lung cancer

Wambaka Ange MAMPUYA, Yukinori MATSUO*, Nami UEKI, Mitsuhiro NAKAMURA, Nobutaka MUKUMOTO, Akira NAKAMURA, Yusuке IIZUKA, Takahiro KISHI, Takashi MIZOWAKI and Masahiro HIRAOKA

The aim of this study was to evaluate the impact of abdominal compression (AC) on outcome in patients treated with stereotactic body radiotherapy (SBRT) for primary lung cancer. We retrospectively reviewed data for 47 patients with histologically proven non-small cell lung cancer and lung tumour motion ≥8 mm treated with SBRT. Setup error was corrected based on bony structure. The differences in overall survival (OS), local control (LC) and disease-free survival (DFS) were evaluated to compare patients treated with AC (n = 22) and without AC (n = 25). The median follow-up was 42.6 months (range, 1.4–94.6 months). The differences in the 3-year OS, LC and DFS rate between the two groups were not statistically significant (P = 0.909, 0.209 and 0.639, respectively). However, the largest difference was observed in the LC rate, which was 82.5% (95% CI, 54.9–94.0%) for patients treated without AC and 65.4% (95% CI, 40.2–82.0%) for those treated with AC. After stratifying the patients into prognostic groups based on sex and T-stage, the LC difference increased in the group with an unfavourable prognosis. The present study suggests that AC might be associated with a worse LC rate after SBRT using a bony-structure-based set-up.
Motion Management Methods

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Keall et al: The management of respiratory motion in radiation oncology report of AAPM Task group 76
Respiratory gating methods

- **AIM** - Irradiate the target volume only when it moves into a predefined position in the respiratory cycle

- **Advantages**
  - Significantly reduces the CTV-PTV margins
  - Patient comfortably breathes freely

- **Radiation beam is on during only a selected segment (30-50%) of the respiratory cycle**

- **Limitation** - Usually takes longer time to deliver the same prescribed dose
Respiratory Gating Methods

Gating using external marker

Gating using internal fiducial markers

Surface Imaging
(e.g. RPM, AlignRT, BreatheWell)
- Respiratory pattern of patient during different breathing phases using RPM
- Dashed lines indicate upper and lower gating threshold (3mm), and determines when gating system turns beam on/off

Sung et al, 2014
Respiratory Gating: pro and con

• Reduces margins for motion > 1 cm
• Dosimetric benefits (lower toxicity)
• Patient-friendly
• Increased room time by 80% and beam-on time by 5.5 x
Motion Management Methods

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Keall et al: The management of respiratory motion in radiation oncology report of AAPM Task group 76
Real-time tumor-tracking methods

Aim: To design radiation beam to follow a moving target by tracking the tumor/organ movement continuously in real-time

Techniques to track tumor position
- External respiratory surrogated
- Implanted radio-opaque fiducial markers
- Surface imaging
PROS & CONS of Tracking technique

PROS
- Reduces the CTV-PTV margins
- Patient comfortably breathes freely
- No interrupt treatment delivery

CONS
- Usually takes longer time
- Fiducial placement might be required
- Risk for pneumothorax, fiducial migration
Dynamic tracking in Robotic Radiosurgery

- Detect tumor position
- Reposition the beam

-> 10 years clinical experience
Robotic Radiosurgery: Internal target position

The internal target position can be extracted from:
- Fiducials
- Tumor density
Robotic Radiosurgery: fiducial-less tracking method

- Track the position of the tumor based on its density
- It works for relatively large tumors
  - 10-15 mm
  - Projection on the camera is not obstructed by the spine or other internal organ
Lung SBRT in Ramathibodi Hospital

CyberKnife®
Since 2008

Edge®
Since 2016
SBRT protocol for Lung cancer (primary non-small cell lung cancer, lung metastasis)

Eligible criteria for patient

1. Patient accept the risk and benefit of this treatment modality
2. Patient can cooperate and understand all the process of treatment

Eligible criterial for disease

1. Histological confirm NSCLC, staging T1N0M0 or T2(\(<\)=5cm ) N0M0
2. Lung metastasis with known primary malignancy
3. Surgical or medical inoperable or patient refuse surgery or no further standard treatment
4. Ideally, size of lesion should be \(<\) 5 cm and less than 4 lesions, however, lesion \(>\) 5 cm can considered for SBRT, if dose constraints can be kept within acceptable
RTOG Lung

<table>
<thead>
<tr>
<th></th>
<th>0236</th>
<th>0618</th>
<th>0813</th>
<th>0915</th>
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<tr>
<td>Prescribed Dose</td>
<td>60Gy/3f</td>
<td>60Gy/3f</td>
<td>50Gy/5f</td>
<td>34Gy/1f vs. 12Gy/4f</td>
</tr>
<tr>
<td>Location</td>
<td>Peripheral</td>
<td>Peripheral</td>
<td>Central</td>
<td>Peripheral</td>
</tr>
<tr>
<td>Allow IMRT?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Inhomogeneity Correction?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

0813 and 0915 Table 1

Timmerman’s definition of centrality

Dose Constraints

Table 1: Conformity of Prescribed Dose for Calculations Based on Deposition of Photon Beam Energy in Heterogeneous Tissue
Workflow for CK SBRT lung

3-5 gold (99.9% pure) fiducials placement under CT guidance. For real time tumor tracking (fiducial as internal surrogate)

7 days (or within 1 month)

immobilization device

undergo a fine-cut 1.5 mm CT scan (full expiration-breath hold phase)

planning

start treatment as soon as possible
The contrast media will be used to identify normal structures

Full expiration breath hold phase will be used (not force expiration)
Target delineation

Gross tumor volume (GTV) = gross disease determined from imaging of CT lung windows

Clinical target volume (CTV) = GTV

Planning target volume (PTV) =
  GTV + 2 mm. for lateral, anterior-posterior margin
  + 4 mm. for superior-inferior margin

OARs = normal lungs, trachea, esophagus, heart, spinal cord
Planning for this case
Problems with CyberKnife

1. Pneumothorax post fiducial insertion

2. Technical problems with fiducial insertion and rotational tracking
   1. Improper positioning of the fiducials
      - track translation – needs at least 1 fiducial
      - track rotation - needs 3 fiducials
   2. Fiducials migration
      - between planning & treatment
      - during treatment, inter and intrafraction (CK-long intrafraction treatment time)
From 21 patients, 32 treatment plans

- >3 fiducials can be used for planning
  13 (61.9%)
- >3 fiducials can be used for intrafraction tracking
  6 (28.5%)
Patient has 3 fiducials but only 2 can be used for tracking
Lung SBRT with Edge system

Target motion > 5 mm and
The patient can hold their breath at least 20 sec?

No  Vac-lock, arm up, abdominal belt (lower lobe lesion)

Non-contrast 4D-CT

iGTV – MIP, Organ -average

PTV, include iGTV plus 0.5 cm uniformly

Free-breath SBRT

Yes

2 sets of inhale breath hold CT

iGTV – sum of 2 set BH CT

Self-held breath hold with RPM monitoring and gating
Immobilization of Edge: Lung SBRT

Respiratory Belt
Breathing instruction during CT simulation

• **Self held inspiration breath hold**
  “Take a breath in, out, in and hold it

• **4DCT**
  “Take a regular and slow breathing, breath in, out, in ......
Respiratory monitoring in Edge® system

• Real-time position management (RPM)
  • Routine use for lung SBRT

• Optical surface monitoring system (OSMS) (Visionrt)
Optical surface monitoring system (OSMS) (Visionrt)

Optical tracking in treatment room acquire real time 3D surface. No additional radiation dose emitted

Rong et al. PLOS ONE 9 (5)
Vision RT schema

During deep inspiration: Fuse planning CT image with real time surface rendering at each fraction
During treatment

Real time deltas acquired in 6 degrees of freedom, displayed & if out of user defined tolerances, system gives couch correction to therapist.

If patients breath hold is out of tolerance before, or during treatment, beam is manually held until correct breath hold amplitude or positioning acquired.
Vision RT schema

Continuous monitoring of patient position during set up and treatment using real time deltas
OSMS in Lung SBRT at our center

• Not routine use for lung SBRT

• Problems when monitor with OSMS
  • Surface image as surrogate, might not correlated with lung tumor motion
  • Depend on the selected surface area
    • If too small – not detect
    • If too large – easy to out of threshold, beam always turn off
On the day of treatment

- Therapist instructed the patient depend on the technique

- CBCT – Before treatment – physician present at the treatment room to verify CBCT and apply shift
  - Middle part of treatment
  - End of treatment (mostly in the first fraction)

- In BH technique - therapist are instructed to turn on the beam only when the target breath-hold level has been achieved and to stop if the level has fallen below a preset tolerance
Inhale BH SBRT with RPM and gating

Upper and lower gating threshold (5 mm), and determines when gating system turns beam on/off

Free breathing SBRT with RPM, no gating
Comment form real practice

• **Fiducial tracking**
  • Pneumothorax risk- accept
  • Ideal for manage intrafraction motion
  • Patient – friendly
  • Staff – less stress if ignore rotation tracking

• **Free breathing with ITV concept, no gating**
  • More friendly to patient and staff

• **Inhale breath hold**
  • Rely heavily on the patient’s ability and perform a reproducible BH
  • Introduce more stress to patient and staff
How we select the patient for each technique?
Tumor motion evaluation by 4DCT

Motion <1cm

- Regular breathing
  - Can tolerate long treatment time

- Fiducial tracking

- Irregular breathing
  - Poor PS, Comorbid
  - Can’t tolerate long treatment

- ITV in MIP phase
  - No gating
Tumor motion evaluation

Motion $\geq 1$ cm

Can tolerate breath hold

Inhale breath hold

Can't tolerate breath hold

Regular breathing

Fiducial Tracking

Irregular breathing

ITV in MIP phase
Summary

• Respiratory motion management is beneficial in the reduction of intrafractional motion
• Allows for a decrease in treatment volumes, resulting in a reduction of normal tissue toxicities while giving higher doses to the lesion
• In indirect monitoring it is essential to validate the correlation between surrogate and tumor position during treatment
<table>
<thead>
<tr>
<th>Methods</th>
<th>Strategies</th>
<th>Techniques</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tumor encompassing</td>
<td>Incorporate all movement</td>
<td>- Slow CT</td>
<td>- May lead to increased risk of normal tissue toxicity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Breath hold CT</td>
<td>- Imaging dose &gt; 2-15 time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- 4DCT</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- CINE MRI</td>
<td></td>
</tr>
<tr>
<td>2. Breath hold</td>
<td>Freeze, control motion</td>
<td>- Deep inspiratory breath hold (DIBH)</td>
<td>- Not feasible in all case</td>
</tr>
<tr>
<td>3. Force shallow breathing with abdominal</td>
<td>Follow or chase tumor</td>
<td>- Active breathing control (ABC)</td>
<td></td>
</tr>
<tr>
<td>compression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Respiratory gating</td>
<td>Intercept or control</td>
<td>Respiratory as surrogate as tumor</td>
<td>- Increase treatment time</td>
</tr>
<tr>
<td></td>
<td>movement</td>
<td>position</td>
<td>- Difficulty in target verification</td>
</tr>
<tr>
<td>5. Real time tumor tracking</td>
<td></td>
<td>Implanted marker and specialized</td>
<td>- Difficult marker insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>treatment delivery</td>
<td>- Increase risk of pneumothorax</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Marker migration</td>
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</table>
Characteristics of proper motion management technique

- Enables to minimize normal tissue included in the radiation field
- Comfortable and reproducible
- Provides target localization during treatment
- Not add significant risk
- Individual patient dependent
  - Extent of target motion
  - Breathing status
  - Other co-morbidities

Selecting the most appropriate motion management option for each patient requires a good understanding of the available technologies and physicist involvement.
Thank you for your attention