Motion Management In Lung Cancer

Dr. Sambit Swarup Nanda
Assistant Professor
Radiation Oncology
HBCH & MPMMCC, Varanasi
Aim & Accuracy
Learning Objectives

➢ Understand the techniques available for motion management, and the relationship between respiration and tumor motion.

➢ Outline the information available in 4DCT images, and the motion management decision making process.

➢ Discuss treatment planning for motion management cases.
Are Lung Tumours Static ??????
Treatment planning limitation with Motion

- Large Margin (Blindly)
- Greater Irradiation area
- Limitation in delivering dose
- More dose to normal structure
What is the Extent of Motion in a lung tumor??


Precise and real-time measurement of 3D tumor motion in lung due to breathing and heartbeat, measured during radiotherapy

Yvette Seppenwoolde, Hiroki Shirato, Kei Kitamura, Shinichi Shimizu, Marcel van Herk,

- Inserted gold markers- 20 patients
- Fluoroscopic real-time tumour tracking system

Seppenwoolde Y et al IJROBP 2002;53:822-34.
Results

➢ Amplitude of tumour motion greatest in cranial-caudal direction
  • Tumours in the lower lobe vs upper lobe
  • Not attached to rigid structures (such as chest wall and vertebrae) vs attached
    • 12±6 mm vs 2±2 mm.

➢ Lateral movement: 1.2±0.9 mm

➢ AP movement: 2.2±1.9 mm

Does LN motion same as lung Primary

Motion analysis of 100 mediastinal lymph nodes: potential pitfalls in treatment planning and adaptive strategies

Jason R Pantarotto 1, Anna H M Piet, Andrew Vincent, John R van Sörnsen de Koste, Suresh Senan

• 100 LN → 41 pts → 4D-CT scans

• Changes in nodal center of mass position.

• Average 3D nodal motion during quiet breathing- 0.68 cm (0.17-1.64 cm)

• Cranial-caudal direction maximum motion. 77% > 0.5 cm, 10% > 1.0 cm

• Strongly associated with nodal station (with lower mediastinal nodes showing the highest motion)

• Node >2cm vs > 2cm : no diff

Need for Motion Management ...
When !!!

- AAPM Task Group 76

- 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”.

- 5-mm threshold - Significant motion artifacts or systematic errors.
Motion Management Techniques

Popular Management Strategies

- Free breathing (design target to compensate for full range of motion)
- Abdominal compression (use a device to limit diaphragm expansion)
- Gating (treat during select portions of the respiratory cycle)
- Active breathing control (patient controls breathing with assistance)
- Dynamic tumor tracking (radiation beam follows target as it moves)
1. Free breathing Technique (Motion Encompassing)

1. Take CT Images in extremes of tumor motion.

2. Deep inspiratory and deep expiratory Images

3. Create ITV from both sequences.
Abdominal Compression

- Forced Shallow breathing by limiting diaphragmatic motion.

- Abdominal compression plate in conjunction with SBRT frame

- Difficult reproducibility, need more imaging

- Difficult for obese and pt with poor respiratory function
Motion Management Objectives

Compensate for tumor motion (monitor respiration and correlate with tumor motion)

Create smaller target volumes (utilize the most stable parts of respiratory cycle to reduce margins)

Decrease radiation to normal tissues (design more precise treatment plans and improve patient outcomes)
Gating
Respiration

Max Inspiration

Max Expiration

Max Inspiration

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 0% (phase)

Longer in Expiration

time (s)
Gating Techniques

No Gating - “NO GATE”

- Treatment is independent of respiratory cycle
- No target motion due to respiration (or compensated for by target margin)

Gating 0%-90% - “GATE 100”

- Treatment throughout “normal” respiratory cycle
- Target motion from normal inspiration/expiration cycle accounted for in ITV
GATE 0%-90%

“GATE100”
Gating Techniques

• Gating 30%-70% - “GATE30-70”
  
  o Treatment during expiration phases (30% to 70%) only
  
  o Target ITV is created from most stable portion of respiratory cycle
GATE 30%-70%
“GATE30-70”
Gating Techniques

• Deep Inspiration Breath Hold - “DIBH”
  
  o Treatment during the max inspiration phase only (inspiration breath hold)
  
  o Target ITV is created from a single respiratory phase
Deep Inspiration Breath Hold “DIBH”

Deep inspiration vs. Regular inspiration
4DCT Concepts

Acquire redundant CT data (helically or axially) to generate images throughout the breathing cycle for each slice.
Retrospective 4D CT Image Acquisition

Respiration Waveform from RPM Respiratory Gating System

"Image acquired" signal to RPM system

X-ray on

1st couch position

2nd couch position

3rd couch position

Inhalation

Exhalation

X SEC
Retrospective 4D CT Image Acquisition

Respiration Waveform from RPM Respiratory Gating System

"Image acquired" signal to RPM system

X-ray on

1\textsuperscript{st} couch position
2\textsuperscript{nd} couch position
3\textsuperscript{rd} couch position
4DCT Images Binning

Individual phase images
- Typically 10 images, representing 10 phases
- Specific snapshots of the anatomy at various points in respiration

Composite images
- Single 3D images generated from the individual phase images
- Used to depict portions of the respiratory cycle (multiple phases)
- Helpful for contouring and treatment planning
- Maximum intensity projection (MIP) images
- Average (AVG) images
Image Binning process

CT Exam

FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME

Couch position

After Exam

Sort images

FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME
FI  MI  ME

Couch position

FI: full inhale
MI: mid inhale
ME: mid exhale
FE: full exhale

Full inhale CT set

Full exhale CT set
Maximum Intensity Projection Image (MIP)

- 3D scan consisting of the greatest voxel intensities throughout the 4DCT scan
- Illustrates the range of tumor motion on a single image
- Tumor position visible in MIP for all of the included phases
- Not accurate for treatment planning (i.e. dose calculation)
Maximum Intensity Projection Image (MIP)

- Useful for contouring ITV
- Doesn’t require 4D visualization capabilities in treatment planning system
- Extremely useful for lung tumors because of the differences in tissue density
- Can be deceptive or uninformative (no significant changes in density)

MIP 30%-70% vs. MIP 0%-90%
Average Image (AVG)

General
- Voxels equal to the arithmetic mean of the 4DCT
- Illustrates average pixel intensity during respiration
- Phases are equally weighted in image
- “Blurring” resulting from tumor motion

Treatment Planning
- Less useful for delineation (i.e. contouring ITV)
- More useful for dose calculation
- Not a perfect representation of tumor
Distorted images, incorrect anatomical positions, volumes or shapes.
Pros and Cons of 4D CT

✓ Motion artifacts are reduced

✓ Tumor and organ spatial & temporal information available

❖ Time consuming

❖ CT tube heating

❖ Data management

❖ Artifacts created by irregular breathing
Active Breath Control

Patient controls breathing with assistance
To perform any type of respiratory gating, it is obvious a *device to monitor breathing* is required.

- Philips bellows
- Varian RPM™
- Sentinel
- Vision RT
4DCT SCAN
4D CT SCAN

Real-time Position Management (RPM)
Infra red plastic box
In room camera
Associated software
Contouring Work flow in our institute

1. **Immobilization**
2. **Training:** min 3 times
3. **CT simulation 4D-CT**
4. **Amplitude Variance < 0.22?**
   - **Yes:**
     - 10 CT -> ITV
     - **Margins:** 5 mm isotropic
   - **No:**
     - AverageCT -> CTV -> “ITV”
     - **Margins:** 5 mm isotropic
Tumor Tracking
Real-time tumor-tracking radiation therapy for lung carcinoma by the aid of insertion of a gold marker using bronchofiberscopy

Real-time tumor-tracking radiation therapy for lung carcinoma by the aid of insertion of a gold marker using bronchofiberscopy
Thank You