Image guidance Strategies for Motion Management

4D and Couch Tracking Slides Courtesy of Prof. Matthias Guckenberger

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Disclosures

Research and Travel Grants from Elekta
Board Member of C-Rad
Overview

- Motion Compensation Strategies
- Breath Hold Imaging and Treatment
- Ultrasound-based positioning
- Does it work clinically?
- Where do we go from here
Overview

- Motion Compensation Strategies

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Motion Compensation Strategies

- 4D Treatment Planning, Individually Adapted Margins
- Breath Hold Treatment
- Gating
- Tracking
  - Robotic Tracking
  - Gimbal Tracking
  - Couch Tracking
  - Sequence Resorting

Imaging Modalities:
2D, 2D/3D, 3D X-ray based
Transponder based
Ultrasound based
Motion compensation techniques: 4D IGRT

Treatment planning

Target volume definition: ITV concept

Pro:
• Large clinical experience
  • Low toxicity
  • High rates of LC
• Short RT delivery times
• Straight work-flow

Cons:
• Larger target volumes
Motion compensation techniques: 4D IGRT

Treatment planning

Target volume definition: respiration correlated 4D-CT

End-exhalation

End-inhalation

Fusion
Motion compensation techniques: 4D IGRT

Treatment planning

Target volume definition:

Motion compensation using the internal target volume (ITV) technique

End-exhalation

End-inhalation
Motion compensation techniques: 4D IGRT

Treatment planning

Target volume definition:

PTV = ITV + 5mm in all directions
Motion compensation techniques: 4D IGRT

Evaluation of patient set-up error
Motion compensation techniques: 4D IGRT

Evaluation of target position in each breathing phase
Motion compensation techniques: 4D IGRT

Treatment planning:
Reference Image

Treatment delivery:
Verification Image

4D IGRT: Registration of corresponding phases
Motion compensation techniques: 4D IGRT

Treatment planning:
Reference Image

Treatment delivery:
Verification Image

End-exhalation as reference: easy for visual verification
Motion compensation techniques: 4D IGRT

Bone set-up

<table>
<thead>
<tr>
<th>Clipbox</th>
<th>Mask</th>
<th>Adjust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tx (cm)</td>
<td>0.00</td>
<td>-0.21</td>
</tr>
<tr>
<td>Ty (cm)</td>
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<td>-0.47</td>
</tr>
<tr>
<td>Tz (cm)</td>
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<td>-0.38</td>
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</tbody>
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Tumor set-up

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Visualization of the effects of base-line shifts
Motion compensation techniques

The concept of Couch and MLC tracking
Motion compensation techniques

Comparison of couch and MLC tracking

Heidelberg: Siemens 160 MLC

Würzburg: HexaPOD Evo
Motion compensation techniques

Comparison of couch and MLC tracking: Geometrical accuracy in lung cancer

MLC

HexaPOD
Motion Compensation Strategies

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  - Gimbal Tracking
  - Couch Tracking
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Imaging Modalities:
2D, 2D/3D,3D X-ray based
Transponder based
Ultrasound based

Guckenberger, Richter, Booda-Heggemann, Lohr, in press
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Boda-Heggemann et al., Radiother Oncol, 2011
Clinical Setup:  
2. Surface-based Surveillance

Stieler et al., SUON, 2012  
Stieler et al., SUON, 2013
Breath hold surveillance
Clinical Setup:
Flow-Based Breath Hold Triggering
Overview

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TPUS & TAUS Fused with CT

5 Clicks
Tracking Possibilities with the Portal Vein
Clinical Setup:
3. Direct Liver Tracking
Overview

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Fallbeispiel hypofraktionierte Lungenbestrahlung

Planungs-CT: 02.09.09
PET-CT: 31.08.09
Radiatio
Sept 2009
Nachsorge-CT: 26.11.09
Nachsorge-CT: 06.10.10

80 jähriger Patient mit NSCLC Stadium I, T2aN0M0
Nebendiagnosen: COPD, Emphysem, KHK, art. Hypertonie
FEV1: 2,3l

Zurzeit lokal kontrolliert und progressionsfrei
Lungen - Ergebnisse

Overall Survival

Progression Free Survival

Local Control

Local Control - abhängig von Dosis

BED2 > 80 Gy

BED2 < 80 Gy
Functional imaging: PET -> complete remission
Local control

A

BED2 > 78Gy
BED2 < 78Gy
p = 0.0999

B

PTV < 67ccm
PTV > 67ccm
p = 0.2412
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Fast kilovoltage/megavoltage (kVMV) breathhold cone-beam CT for image-guided radiotherapy of lung cancer

Hansjoerg Wertz\textsuperscript{1,5}, Dzmitry Stsepanou\textsuperscript{1}, Manuel Blessing\textsuperscript{1}, Michael Rossi\textsuperscript{2}, Chris Knox\textsuperscript{3}, Kevin Brown\textsuperscript{3}, Uwe Gros\textsuperscript{2}, Judit Boda-Heggemann\textsuperscript{1}, Cornelia Walter\textsuperscript{4}, Juergen Hesser\textsuperscript{1}, Frank Lohr\textsuperscript{1} and Frederik Wenz\textsuperscript{1}

kV

MV

http://www.elekta.com/healthcare_international_beaumont_work_results_breakthrough.php
Conclusion

Several motion compensation strategies successfully reduce motion effects in clinical radiotherapy.

Breath hold treatments under IGRT control are easy to perform and precise.

Ultrasound is a very precise positioning tool, particularly suited for breath hold liver radiosurgery and is ideal for noninvasive continuous target surveillance/tracking where applicable.

Clinical results with these strategies are good.