IGRT for SBRT and particle therapy

Matthias Guckenberger, MD
Outline

1. Rational for IGRT
2. Technologies for IGRT
3. Pitfalls and challenges in IGRT
4. Clinical evidence for IGRT
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1. Rational for IGRT
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Rational for IGRT

Traditional patient set-up: skin marks

Constant relationship between skin marks and internal anatomy?
Rational for IGRT

Inter-fractional base line shifts in lung SBRT

Patient positioning | Bone set-up | Tumor set-up

Base-line shifts independently from the bony anatomy
Rational for IGRT

Inter-fractional base line shifts in lung SBRT

Mean: 5.3mm  90th percentile: 8mm  
Guckenberger et al. 2006

Mean: 6.8mm  90th percentile: 13.9mm  
Prudie et al. 2007
**Dosimetric effects in “Photon” SBRT**

- ITV concept
- 5mm PTV margin

**No IGRT**
- Minimum CTV dose
  - 6% on average
  - -50% on maximum

**IGRT**
- No relevant dose loss
Rational for IGRT

Dosimetric effects in “Proton” SBRT

Increased complexity in Proton SBRT to compensate
• Tumor volume / shape changes
• Breathing motion
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Technologies for in-room IGRT

3D volume imaging
- In-room CT
- Cone-beam CT
- MV CT

2D kV stereoscopic imaging

2D & 3D imaging
Image quality of in-room CT imaging

- Intra-pulmonary targets clearly visible in all imaging modalities
- IQ for mediastinum suitable only in kV helical CT
Integration of 4th dimension into IGRT

Planning

Respiration correlated CT

4D IGRT

Treatment

Respiration correlated CBCT

Technologies for IGRT
Where 4D CB-CT improves accuracy

Mobile tumors located immediately superior the diaphragm
Technologies for IGRT

2D IGRT – implanted markers

- Markers required: poor soft-tissue contrast
- Surrogate, not the target itself
Technologies for IGRT

# 2D IGRT – implanted markers

<table>
<thead>
<tr>
<th></th>
<th>Type of markers</th>
<th>Implantation method</th>
<th>Success rate</th>
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<tr>
<td>de May 2005</td>
<td>Coils</td>
<td>Transthoracic</td>
<td>100%</td>
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- **Seeds**: high marker migration rate
## 2D IGRT – implanted markers

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<tr>
<th></th>
<th>Type of markers</th>
<th>Implantation method</th>
<th>Success rate</th>
<th>Pneumothorax</th>
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<td>0/8</td>
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<td><strong>B gagat 2010</strong></td>
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<td>99.3% 85.3%</td>
<td>23% 54%</td>
<td>3% 29%</td>
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- Seeds: high marker migration rate
- Transthoracic approach: high rates of pneumothorax
  - Transbronchial implantation of Coils
Technologies for IGRT

2D kV IGRT – markerless tracking

DRR = Reconstruction (plan CT) simulating orthogonal X-rays

Bilateral in-treatment X-rays at 45° from each side of patient

DRR + X-rays match using intensity pattern recognition

Bahig IJROBP 2013
2D kV IGRT – markerless tracking

Target diameter

“We recommend considering tumor tracking in all patients with tumors >3.5 cm based on >80% chance of adequate tumor visualization in this subgroup”

- Strategy in remaining 20%?
- 95% success rate requires tumor diameter >5cm

Predictors for successful markerless tracking

- Tumor size
- Volume
- Density
Technologies for IGRT

2D MV IGRT – markerless tracking

EPID for target monitoring during SBRT

Pros:
• Passive monitoring w/o additional irradiation dose or additional hardware

Cons:
• Successful in < 50% of SBRT cases
• Requires 3D-CRT
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Non-rigid uncertainties in NSCLC

Treatment planning

IGRT treatment

Target Spinal cord

Volume

Dose

Target Spinal cord

Volume

Dose
Dosimetric effects of base line shifts: ORGANS AT RISK

Dose variability

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<tr>
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<tbody>
<tr>
<td>Cord</td>
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<td>PBT</td>
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<tr>
<td>Aorta</td>
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Galerani IJROBP 2010

ELCC 2014 - Matthias Guckenberger
Clinical relevance of differential motion
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Clinical evidence for IGRT

(Missing) Evidence in lung SBRT

Patterns of care and outcome in Germany and Austria:

n=582
(Missing) Evidence in lung SBRT

Patterns of care and outcome in Germany and Austria
(Missing) Evidence in lung SBRT

Clinical evidence for IGRT

Rapid adoption of SBRT at least partially result of IGRT:
- Confidence in high-dose per fraction radiotherapy
- Improved and streamlined work-flow
CONCLUSIONS

• Image guidance broadly available on all modern linacs

• Major **benefit** of volumetric IGRT: 3D and 4D visualization of target and OARs

• Major **disadvantage** of volumetric IGRT: slow and limited usability for intra-fraction monitoring

• Both 2D and 3D imaging suitable for lung SBRT

• Integration of 4D breathing motion is essential

➢ Image guidance a mandatory QA procedure in SBRT