Image Guided SBRT II: Challenges & Pitfalls
Dosimetric Challenges & Pitfalls
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Introduction
Recent technical developments substantially improved SBRT
Making it a useful tool for therapy.

Outline
Dosimetric Challenges & Pitfalls
- Dosimetric considerations in small field dosimetry
- Dosimetric considerations in calculation grid size
- Dosimetric considerations in imaging artifacts
- Dosimetric effect of couch attenuation
- Dosimetric considerations in 4D CT
- Dosimetric considerations in online imaging

Outline
> Image-guided stereotactic body radiation therapy (SBRT)
> Review of dosimetric challenges & pitfalls
> Review of clinical challenges & pitfalls
> Review of technical challenges & pitfalls
> Questions and Discussions
**Small Field Dosimetry**

- Small field dosimetry ($\leq 3\text{cm} \times 3\text{cm}$) may have challenges, including non-equilibrium condition and high dose gradients in a small region, especially for small field SBRT.
- Small radiation field dosimetry in SBRT has been investigated intensively in the past:

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**Calculation Grid Size**

- Since TPS are used clinically, the uncertainty associated with calculation grid size has been an issue.
- Even today, with 3D and IMRT TPS, dose uncertainty due to grid size is still a concern.
- It is desirable to have an optimal grid size for specific clinical applications
Calculation Grid Size

- Four different dose calculation grid sizes were considered (1.5 mm, 2 mm, 3 mm and 4 mm).

Phantom


Calculation Grid Size

Optimal grid size for a specific clinical application?

Phantom


Calculation Grid Size

Lung SBRT using DCAT

Patient


Calculation Grid Size

10-degree

2-degree

Phantom

Calculation Grid Size

Lung SBRT using DCAT

A parameter set with a 3-mm grid size and a 4° angular increment is found to be appropriate for predicting patient dose distributions with a dose difference below 1% while reducing the computation time by more than half for lung SBRT using DCAT.


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Imaging Artifacts

- CT simulation plays an important role in RT by providing 3D anatomical image data for treatment planning.
- CT images provide excellent anatomical information to enable organ contour and accurate localization of tumors and organs at risk for treatment planning.
- CT images provide CT numbers (Hounsfield unit) to account for attenuation for heterogeneity correction in dose calculation.


CT-Simulators

- Conventional CT simulators (~70 cm diameter) will often not fit immobilizers or extra large patient.
- CT simulators with wide-bore of 80–90 cm diameter were designed to address these issues.
- To maintain image quality, some of the wide-bore CT scanners still maintain conventional maximum scan FOV of 50 cm. The reconstructed FOV may be larger than the sFOV, but with truncated projection data and compromised image quality for large objects.

Imaging Artifacts

- Metal artifacts in computed tomography (CT) appear as dark and bright streaks arising from implants.
- Metal artifacts obscure important information regarding OAR and tumor.
- Errors in CT numbers is a concern in RT treatment planning.


Imaging Artifacts

- Spine SBRT is frequently delivered to patients with spinal hardware such as titanium rods.

Imaging Artifacts

- Metal artifacts can introduce dosimetric errors in spinal SBRT treatment planning.
- Using a CT-density table with a maximum density of 1.82 g/cc is a practical way to reduce the dosimetric error from the artifacts, but could underestimate the dose perturbation.
- When a significant amount of hardware in the beam path, to manually override the density of titanium hardware to 4.5 g/cc in dose calculation is recommended.


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Couch Attenuation

- In RT, treatment planning is to be dosimetrically and geometrically accurate.
- To achieve the best possible treatment accuracy, the couch should be stiff in order to avoid any sagging effects of the table.
- Couch should not create any imaging artifacts that might decrease the setup accuracy of the treatment.
- However, existence of couch does attenuate radiation beam.

Couch Attenuation

Dose differences with and without couch in 1, 2, 3 Gy lines (70 Gy Rx)


Couch Attenuation

IMRT

VMAT


Couch Attenuation

Six prostate patients selected for the study, with RA. Each patient, two targets were defined, PTVI (70 Gy) including prostate gland and PTVII (50 Gy) including seminal vesicles and areas at risk.

Table 3: Difference between plans calculated for the thick couch model and for the no-couch model.

<table>
<thead>
<tr>
<th>Organ</th>
<th>6 MV</th>
<th>15 MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTVI</td>
<td>1.3 ± 0.3</td>
<td>0.9 ± 0.2</td>
</tr>
<tr>
<td>PTVII-PTVI</td>
<td>0.7 ± 0.2</td>
<td>0.5 ± 0.1</td>
</tr>
<tr>
<td>Remain</td>
<td>0.6 ± 0.2</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Bladder</td>
<td>0.6 ± 0.2</td>
<td>0.4 ± 0.1</td>
</tr>
<tr>
<td>Fingers</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>Healthy tissue</td>
<td>0.2 ± 0.1</td>
<td>0.1 ± 0.1</td>
</tr>
</tbody>
</table>


Couch Attenuation

- There are significant and potential clinical impact discrepancies at the level of the target volumes if calculations are performed without couch and delivery is with couch.
- The effect is particularly relevant at low energy (6 MV in this case).


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Dose Calculation with 4D CT

- 4DCT allows physicians to take into account the tumor motion when delineating target volumes.
- Remains controversial how to accurately calculate and verify the planned dose compared to the delivered dose for a continuously moving target with surrounding critical organs.
- Recently, dose is calculated based on spatial and temporal information of tumor and normal tissue derived from 4DCT.


20 patients with lung lesions were evaluated for this study.

No significant differences in dosimetric parameters for both PTVs and lung between FB plans and AIP plans. AIP datasets are more suitable because AIP datasets were less prone to artifacts.

MIP plans tend to provide significantly smaller low-dose region in lung compared to AIP plans. However, decrease was mainly caused by change of lung volume. So, MIP plans tend to be underestimated or overestimated when lesions are close to denser tissues.

AIP seems favorable for planning and dose calculation for lung SBRT.

Imaging Dose

Image guidance has emerged for patient positioning and target localization in radiotherapy.

Imaging dose received as part of treatment has long been regarded as negligible.

Introduction of more intensive imaging procedures for IGRT now urges clinicians to evaluate therapeutic and imaging doses in a more balanced manner.

**Pediatric Imaging Dose**

Although daily imaging dose is of little additional radiation risk compared with a radiotherapy treatment, summed imaging organ doses may become important if more CBCT scans are used.

Dose to critical organs depends on anatomic site, tissue composition, and locations of OARs, and scan settings.

Including imaging dose in a commercial TPS is desirable and feasible.

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**Imaging Dose**


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**Summary**

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