Prospective Dosimetric Data Generation For Every Patient And Fraction To Analyze Results On Radiation Oncology Patient Registries

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Radiation Oncology Registries (ROR) are important tools in the era of evidence-based medicine. Dosimetric information currently in RORs is typically limited to treatment planning information – only a first snapshot of the actual dose to be delivered.

To better understand the correlation between dosimetry and a particular clinical outcome, it is desirable to have knowledge of the daily and cumulative dosimetric information based on data gathered during treatment.

An automated system composed of Adaptive Dose Recalculation (ADR) and In-Vivo verification (IV) for every patient and every fraction has been deployed in all of the clinics in our network to prospectively generate actual dosimetric data during treatment.

The dosimetric results from 3,687 ADR patients and 150,330 IV fractions are presented here.
Materials and Methods

For each patient and fraction, the following data are automatically generated on daily basis immediately after treatment:

Adaptive Dose Recalculation:

- [Image of adaptive dose recalculation]

In Vivo Verification:

- [Image of in vivo verification]

Treatment beam passes through the patient and the signal is collected by the imaging detector.
Materials and Methods

For each patient and fraction, the following data are automatically generated on daily basis immediately after treatment.

**Adaptive Dose Recalculation provides:**

- Flagging system dashboard

**In Vivo Verification provides:**

...
## Adaptive Reports Summary

<table>
<thead>
<tr>
<th>Patient ID</th>
<th>Patient name</th>
<th>Physician</th>
<th>Plan label</th>
<th>Last treatment</th>
<th>Fx treated</th>
<th>Review advised</th>
</tr>
</thead>
<tbody>
<tr>
<td>C95645ESOPHexped</td>
<td>2014-03-04 08:16:40</td>
<td>2 / 35</td>
<td>BRACHIAL PLEXUS</td>
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<td></td>
<td></td>
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<tr>
<td>C93654 PTVmodi</td>
<td>2014-03-03 13:42:54</td>
<td>10 / 18</td>
<td>LT LENSE LT_PAROTID RT LENSE</td>
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</tr>
<tr>
<td>C92047 BOTBST1i</td>
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<td>2 / 5</td>
<td>CTV20</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>C93654LTNECKi</td>
<td>2014-02-14 13:25:20</td>
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<td>LT LENSE LT_PAROTID RT LENSE</td>
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<td>2 / 33</td>
<td>in lung #mod lung</td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td>2 / 25</td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>C62501LTCHSTWLLi</td>
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<td>30 / 30</td>
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<td></td>
<td></td>
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<tr>
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<td>10 / 10</td>
<td>CTM PTV brainstem</td>
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<tr>
<td>C48256 HYPOPHAR</td>
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<td>25 / 25</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>C47022 LT SKULL</td>
<td>2012-03-08 08:34:12</td>
<td>23 / 30</td>
<td>BRAINSTEM OPTIC NERVE left parotid</td>
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<td>C92047 BOTNODEI</td>
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<td>0 / 13</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Cumulative
- Fx25: Dmean = 27.5 Gy (expected 25.0 Gy)

### Daily
- Fx02: Dmean = 15.6%
- Fx03: Dmean = 35.7%
- Fx05: Dmean = 25.2%
- Fx06: Dmean = 32.1%
- Fx09: Dmean = 19.4%
- Fx10: Dmean = 16.0%
- Fx12: Dmean = 21.5%
- Fx17: Dmean = 25.4%
- Fx18: Dmean = 16.5%
- Fx20: Dmean = 21.1%
- Fx22: Dmean = 24.1%
- Fx23: Dmean = 18.2%
- Fx24: Dmean = 17.5%
Materials and Methods

For each patient and fraction, the following data are automatically generated on daily basis immediately after treatment.

**Adaptive Dose Recalculation provides:**

- Flagging system dashboard
- Fraction and cumulative dose reconstruction during and at the end of the treatment course

**In Vivo Verification provides:**
Daily and Cumulative Dose Analysis Display

daily dose fraction 26

cumulative dose up to fraction 26
Materials and Methods

For each patient and fraction, the following data are automatically generated on daily basis immediately after treatment

**Adaptive Dose Recalculation provides:**

- Flagging system dashboard
- Fraction and cumulative dose reconstruction during and at the end of the treatment course
- Fraction and cumulative DVH during and at the end of the treatment course

**In Vivo Verification provides:**

-
Daily and Cumulative DVH

Daily DVH of fraction 26 treated on 20130403

Cumulative DVH up to fraction 26 treated on 20130403

*solid = planned, symbol = fraction, dashed = deformed/cumulative

slide here to change fraction:

ANT MOUTH

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For each patient and fraction, the following data are automatically generated on daily basis immediately after treatment

**Adaptive Dose Recalculation provides:**
- Flagging system dashboard
- Fraction and cumulative dose reconstruction during and at the end of the whole treatment
- Fraction and cumulative DVH during and at the end of the whole treatment
- Fraction deformable registrations and fraction structure sets
- Several dosimetric and anatomical metrics during treatment

**In Vivo Verification provides:**
- Fraction in vivo dosimetry based on exit detector portal dosimetry
- Patient offsets trending
- Patient registration consistency metric
- Patient positioning based on actual machine encoders
- Machine output behavior
Synergy Between IV and ADR

- Left Chest Wall Sarcoma
Synergy Between IV and ADR

Table 2.2. Treatment Summary

<table>
<thead>
<tr>
<th>fraction#</th>
<th>date time</th>
<th>IGRT</th>
<th>translation</th>
<th>rotation</th>
<th>similarity</th>
<th>outputMean</th>
<th>outputVar</th>
<th>gamma</th>
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<td>IGRT</td>
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<td>Green</td>
<td>Yellow</td>
<td>Green</td>
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<td>2</td>
<td>2012023 111500</td>
<td>IGRT</td>
<td>Green</td>
<td>Green</td>
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<tr>
<td>3</td>
<td>2012024 112553</td>
<td>IGRT</td>
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<td>Red</td>
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<td>2012029 113233</td>
<td>IGRT</td>
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<td>Yellow</td>
<td>Green</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
</tbody>
</table>

Fraction 3 is flagged for review

Adaptive Reports Summary

Fraction 3 is flagged for review

Cumulative
- $D_{mean} = -4.2\%$ (expected $-4.0\%$)

Daily
- Fx03: $D_{mean} = -8.5\%$
- Fx24: $D_{mean} = -5.0\%$
Fraction 3 DVH indicates a difference in planned vs delivered dose
Dose Display - Fraction 3

Breast Position
Is Correction Necessary?

Cumulative dose trend chart indicates that the dose to the chest wall PTV likely did not need to be corrected for the one time event associated with fraction 3.
Patient offsets larger than 3 mm that couch was not moved

Data collected during 3 years

Period 153,330 fractions

Average rate of occurrence:

0.0013 % per year per clinic
Cumulative Dose Flags after Treatment Course

% Patients out of QUANTEC tolerance (no adaptation)
Comparison between Parotids: Planned and Actual NTCP

Patients that deviate adversely respect to plan

NTCP computed using data from Moiseenko et. al JROBP 82 1108 (2012)
Cumulative Dose Flags after whole treatment

% Patients out of QUANTEC tolerance (no adaptation)
Percentage of Patients Having a Target Flag

- Percentage of Patients Flagged for different treatment areas:
  - Abdomen: 8%
  - Brain: 2%
  - Breast: 2%
  - HN: 2%
  - Lung: 8%
  - Other: 10%
  - Pelvis: 4%
  - Prostate: 2%

Legend:
- PTV D95↓ 10% resp. to plan
- PTV D95↑ 10% resp. to plan
- PTV Dmean↓ 10% resp. to plan
- PTV Dmean↑ 10% resp. to plan

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Take Home Messages

- On many occasions, treatment planning information is not the adequate surrogate for Radiation Oncology Registries to describe what happen dosimetrically during treatment.

- Most deviations are the result of patient setup and/or anatomic changes.

- These deviations are hard to predict for a particular patient; therefore, this type of information needs to be recorded for every patient, every day.

- Some human errors can be solved using not only image guidance but also “Dose Guidance”.

- Opportunity to correct for many deviations by treatment adaptation.
Thank You