Data Driven Automation and Practice Quality Evaluation

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Disclosures

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Levels of Big Data

- Population Health-Registry
  - Environmental influences
  - Socioeconomic factors
  - Region of interest
- Quality Reporting
  - Regional incidence
  - Environmental influences
  - Population quality improvement
  - Safety
- Decision Support
  - Outcome/toxicity prediction
  - Individualized treatments
  - Large random sample of patients
- Research
  - Biological questions
  - Clinical trials
  - Statistically sufficient patients

Low granularity/Low cost

High granularity/High cost

Data for quality control

- Indications
  - Diagnosis, staging and histology
  - Guidelines
- Radiation
  - Prescription
  - Regions of interest
  - Dosimetry
  - Beam delivery (logs)
  - Imaging
- Patient outcomes
  - Clinician assessed toxicity
  - Patient reported
  - Disease response

Measures for quality control

- Dose goals (DVH)
- Dose measurement (IMRT QA, diode)
- Delivery complexity (IMRT modulation)
- Region of interest features (volume)
- Patient localization (imaging and couch)
- Patient toxicity (modeled and measured)
- ...
What does it mean to be data driven?

- Protocols are population based
- Each patient is different
- Data can provide personalization within population based guidelines
- Prediction models and refined cohort selection provide patient-specific guidelines

Learning health system to support quality and safety

- Knowledge Database
- Feature Extraction
- Anomaly Detection
- Statistical Models
- Machine Learning
- AI
- Quality Metric Predictions
- Patient Outcome Predictions
- Safety and quality check examples
- Radiotherapy workflow
Potential data driven checks

- Region of interest anomalies
- Dose goals
- NTCP, TCP
- Treatment plan complexity
- Rx appropriateness

Contour integrity

Veeraj Shah

Data-driven Contiguousness

For parallel organs, OAR2 is more easily spared.
For serial organs, OAR1 is more easily spared.

OVH: serial vs parallel
Shape-dose relationship for radiation plan quality

For a selected Organ at Risk and %V, find the lowest dose achieved from all patients whose %V is closer to the selected target volume?

Decisions:
- Plan quality assessment
- Automated planning
- IMRT objectives selection
- Dosimetric trade-offs
Predicted Achievable Dose Objectives

15 pts: OAR Sparing among CP, OP1 and OP2

Table 4. Summary of the dosimetric results for the OPs in the three sets of plans.

<table>
<thead>
<tr>
<th>OAR</th>
<th>Endpoint</th>
<th>CP</th>
<th>OP1</th>
<th>OP2</th>
<th>Wilcoxon z</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>cord4mm</td>
<td>Dmax</td>
<td>6.8</td>
<td>6.7</td>
<td>6.6</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>cord4mm</td>
<td>Dmean</td>
<td>6.3</td>
<td>6.2</td>
<td>6.1</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>brainstem</td>
<td>Dmax</td>
<td>7.4</td>
<td>7.3</td>
<td>7.2</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>brainstem</td>
<td>Dmean</td>
<td>7.0</td>
<td>6.9</td>
<td>6.8</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>contra-lateral parotid</td>
<td>Dmax</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
<td>0.001</td>
<td>0.03</td>
</tr>
<tr>
<td>contra-lateral parotid</td>
<td>Dmean</td>
<td>7%</td>
<td>7%</td>
<td>7%</td>
<td>0.001</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Significantly lower in both OPs: cord4mm (~6 Gy), brainstem (~7.4 Gy) and contra-lateral parotid (~7%).

Barbin Wu

Figure 3: A secondary study on Radiation Therapy Oncology Group (RTOG) 0126 quantified excess risk of late rectal complication due to sub-optimal IMRT planning. (a) Data-driven prediction of normal tissue complication probability (NTCP) vs. the actual treated plan NTCP. (b) Frequency histogram showed a mean excess risk of 4.7%±3.5%.

NTCP quality using KBP

(b) Absolute Excess Risk

Courtesy of Kevin Moore
Physics new start check

Radiation prescription safety

Alert: when uncommon Rx
Radiation prescription safety

Importance of model update

Minuro Nakatsugawa

July 15, 2019

Importance of model update

Minuro Nakatsugawa

July 15, 2019
How to stay safe and maintain quality?

- Data is not always the highest quality – must make sure methods/models don’t assume it is.
- Data does not contain all knowledge. Existing knowledge is often absent.
  - If all patients in database meet a dose goal, then there is no knowledge outside of that goal contained in the data.
  - Be wary of situations where you may be outside of the available data bounds.
- Data gets old.
  - How to keep models current?
  - Do we want to be treated the way patients were treated 2 decades ago?
  - The Rx anomaly may be using an old Rx that has been superseded.

Summary

- Quality follows a system of checks.
- Predefined checklists and scorecards provide population level quality.
- Data driven methods can personalize the measures of quality.
- The learning health system concept offers the opportunity to include data driven quality systems into clinical practice.

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Manufacturing Quality

- Do things the same way every time
- Control of process
- Testing samples
- Feedback from measures

But each patient is different

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Toxicity Prevalence

(P. Lakshminarayanan)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mucositis</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Xerostomia</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Dysphagia</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Taste (Dysgeusia)</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Weight Loss</td>
<td>&lt;3</td>
</tr>
</tbody>
</table>

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Which patient will do better?

69-year-old man with Stage Squamous cell carcinoma, NOS of the Malignant neoplasm of larynx

45-year-old man with T3 N2b M0 Stage IV A Squamous cell carcinoma, NOS of the Malignant neoplasm of larynx