Patient Specific QA for New Technologies and Online Adaptive Radiotherapy

Halcyon & Ethos

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RETHINKING MEDICAL PHYSICS
Disclosures

- Receive Grant Funding from Varian Medical Systems
Outline

- In vivo Patient Specific QA
  - Errors that can be detected/Quality improvements
  - How to encourage implementation
  - Patient management
  - Halcyon

- Online Adaptive Radiotherapy
  - Risk profile
  - Patient Specific QA Challenges/Approaches
  - Ethos
Analysis of Incident Reports

- Review of incidents reported in continual safety improvement (CSI) database.
  - 343 events with 3 or 4 rating (severe or critical)
- Group into “error modes”.
- Determine which errors can ideally be detected by EPID measurements. Pre-treatment or in-vivo.
- For each error mode, compute fraction of events that can be detected.

Bojechko et al. Medical Physics 42 (9), 5363-5369
## Errors Detected

<table>
<thead>
<tr>
<th>Potential Error</th>
<th>Error Type</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine-related</td>
<td>Transfer error</td>
<td>Mans et al. (2010), Mijnheer et al. (2015)</td>
</tr>
<tr>
<td>Plan-related</td>
<td>Dose calculation error</td>
<td>Mans et al. (2010), Fidanzio et al. (2015), Mijnheer et al. (2015)</td>
</tr>
<tr>
<td>Immobilization system not included in the treatment plan</td>
<td></td>
<td>Fidanzio et al. (2015)</td>
</tr>
<tr>
<td>Bolus material not taken into account</td>
<td></td>
<td>Mijnheer et al. (2015)</td>
</tr>
<tr>
<td>Patient-related: anatomy changes</td>
<td>Changes in atelectasis and pleural effusion</td>
<td>Piermattei et al. (2009), Mans et al. (2010), Persoon et al. (2012), Wendling et al. (2012), Persoon et al. (2013), Fidanzio et al. (2015), Mijnheer et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>Variation in patient contour when the patient becomes more relaxed during treatment</td>
<td>Mans et al. (2010), Fidanzio et al. (2015), Peca et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>Gas pockets in the planning CT scan resulting in an underdose in the PTV during treatment</td>
<td>Camilleri et al. (2014), Cilla et al. (2014), Fidanzio et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>Weight loss resulting in an overdose in the PTV during treatment</td>
<td>Mans et al. (2010), Camilleri et al. (2014), Cilla et al. (2014, 2016)</td>
</tr>
<tr>
<td></td>
<td>Incomplete bladder filling resulting in an overdose in the PTV during treatment</td>
<td>Ricketts et al. (2016)</td>
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<td>Patient-related: delivery errors</td>
<td>Bar of the treatment couch in the entrance beam during treatment</td>
<td>Piermattei et al. (2009), Fidanzio et al. (2015)</td>
</tr>
<tr>
<td></td>
<td>Imperfect immobilization allowing the patient to move during treatment</td>
<td>Hanson et al. (2014), Cilla et al. (2016)</td>
</tr>
<tr>
<td></td>
<td>Wrong patient setup during treatment</td>
<td>Fidanzio et al. (2015), Mijnheer et al. (2015)</td>
</tr>
</tbody>
</table>
Aids to Implementation

- Currently in clinical use
  - In-house Solutions
  - Commercial Products (Perfracion, EPIgray, Dosimetry Check, SOFTDISO)

- How to Expand Use
  - Automation
  - Knowledge of system capabilities
  - High sensitivity and specificity in error detection
  - Clinically actionable information
  - Easy to commission
Halcyon

- Delivery on Halcyon, automatically collects EPID images.
  - UCSD started using Halcyon fall 2017, lots of data already collected
- Free data lying around. What can we do with it?
  - Per-fraction patient specific QA
  - Detection of patient related errors
  - Changes in patient anatomy
- Pretreatment PSQA is done with EPID and gamma analysis
Automation

Image and treat ➔ Task Scheduler ➔ Automated download of EPID images ➔ Image sorting based on MRN, plan and date

Fraction 1 ➔ Calculate GDSA mean per patient ➔ Errors
• 3 consecutive >3%
• >10%

EPID Image Analysis ➔ Calculate mean and standard deviation for all treatment in given day ➔ Long report emailed to physicist

 ➔ Upload the mean and standard deviation to TQA ➔ Review and Action

Courtesy of A. Chalise
Clinically actionable information

Steers et al. Medical Physics 47 (11), 5419-5427
Patient Errors

Head & Neck weight loss

Plan 1

GDSA mean

1 month

1 week

# Fraction

Fraction #24

CT

Bojcheko / AAPM COMP 2021 / #10
Patient Errors

Gas bubble - Prostate

GDSA mean

3 months Fraction

Bojechko / AAPM COMP 2021 / #11
Further Developments

- How to Expand Use
  - Automation
  - Knowledge of system capabilities
  - High sensitivity and specificity in error detection
  - Clinically actionable information
  - Easy to commission
Online Adaptive Radiation Therapy

- Workflow is substantially changed from standard IMRT
  - Utilizing on-treatment imaging to assess the patient and replan.
Identifying Errors

- FMEA analysis of ART compared to standard IMRT.
- For ART
  - Identified different, but not more, risks than standard IMRT.
  - Can be implemented with proper mitigations.

<table>
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<th>Failure</th>
<th>QC strategy</th>
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<tr>
<td>(1) Isocenter documentation</td>
<td>Automated isocenter capture, checklists, monitoring trends in daily patient shifts</td>
</tr>
<tr>
<td>(2) Miscommunication of planning directives and failure to properly account for dose accumulation</td>
<td>Well-defined protocols, stable clinical workflow, staff training, integrated record management, electronic physician order, and whiteboard systems</td>
</tr>
<tr>
<td>(3) Poor dataset fusion</td>
<td>Automated fusion tools, specialty training for onsite staff</td>
</tr>
<tr>
<td>(4) Incorrect target/structure delineation and construction</td>
<td>Automated contour integrity verification software</td>
</tr>
</tbody>
</table>
| (5) Poor plan optimization and or incorrect dose computation | Automated software verifying:
  • dose computation
  • leaf sequencing
  • plan integrity |
| (6) Poor plan review                               | Automated comparisons between planning goals and achieved goals, decision support software |
| (7) Incorrect interpretation of plan data for treatment delivery | Independent verification software comparing data indicated by the planning to data read by the delivery system |
| (8) Failures in treatment parameter setup on treatment machine | Simulated delivery, pretreatment (running gantry rotations and MLC patterns without dose output) |
| (9) Failures occurring during treatment delivery   | Retrospective MLC QA, post-treatment                                         |
|                                                   | Transmission detectors                                                      |
|                                                   | Real-time MLC/gantry monitoring                                              |

Challenges for PSAQ in ART

- Patient specific & Plan specific QA
- For initial plan pretreatment QA can still be done
- For online adaptation
  - Predelivery not feasible when patient is on the table
  - Additional plans created frequently increasing workload
  - Must be performed in an accelerated time frame
Approaches

• Using data from machine log files.
  • Perform a “dry-run”
  • Retrospective analysis
  • Real time

• Independent secondary dose calculation

• Transmission measurements
  • Comparison with expected image
  • Back-projection to calculated dose
Ethos

Deformable Image Registration

Online adaptive

Auto/manual contouring

Contours satisfactory

Prediction of Dose delivery

Dosimetry in specification

Replanning

Clinical criteria met

Passed Plan QA

Treatment delivery

Secondary Independent Dose Calc

Retrospective Analysis of Log Files

Glide-Hurst et al. Int J Radiation Oncol Biol Phys, Vol. 109, No. 4
MobiusAdapt

- **Mobius3D**
  - Performs second check on treatment plans
  - Uses independent collapsed cone convolution/superposition algorithm.

- **MobiusFX**
  - Uses Trajectory Log Files, MLC encoder data.
  - Ensure that planned = delivered
• Initial plan QA
  • Plan check with Mobius3D
• On-couch QA
  • Scheduled and adapted plan checks
• Delivery QA
  • Use log files to compute dose and compare to plan that was delivered
Conclusions

• New treatment platforms will help shifting PSQA to include more Patient information
• With newer platforms/more data available
  • In-vivo images
  • Adapted contours, dose distributions
  • Log file data on a per/fraction level
• More per-fr