Patient-Specific QA: Challenges and Opportunities

Moyed Miften, Ph.D.
Professor and Chief Physicist
Department of Radiation Oncology
University of Colorado School of Medicine

Technology and Methods Evolve

Patient-Specific QA Classification
- Measurement (most common and considered the gold standard)
  - ArcCheck, Delta4, Octivus, EPID…etc
- Computational
  - Logfile
  - MU checks
- Hybrid
  - Dose reconstruction
Patient-Specific QA: Current Paradigm

- Plan is computed on a phantom to calculate dose in the QA measurement geometry.
- Phantom is irradiated under the same conditions to measure the dose.
- Calculations and measurements are compared and approved or rejected using the institution’s criteria for agreement.
- QA is performed before treatment.

Patient-Specific QA: Challenges

- Phantom-based QA and patient dose distributions are different due to their differing geometries.
- Phantom QA plan does not check for errors arising from:
  - TPS management of heterogeneities
  - Segmentation errors
  - Patient positioning misalignments or patient anatomy changes

Patient-Specific QA: Challenges

- Analysis of dose difference from Perpendicular Composite delivery/integrated transit planar dosimetry is limited.
  - Requires much time and experience
  - Does not correlate well with anatomy changes in the patient
  - Dose differences can average out based on the arc trajectory, resulting in minor or no indication of potential errors
Ideally…..

- Dose comparison would be in patient geometry
- Dose criteria would be customized for each organ and the dose level found in that organ in order detect clinically relevant errors.
  - Tumor dose tolerance specification might be 3%, while a looser criterion of 10% might be acceptable to muscle receiving 10 Gy.
  - The spatial accuracy requirement might be 2 mm at the edge of the spinal cord, but 5 mm or more in the muscle.

Technologies are becoming more reliable so why more R&D

- Rate of complex radiation treatments are rapidly increasing
- Linacs and their performance are NOT static
- Patient anatomy changes during treatment
- Need to detect clinically relevant errors

QA Practice Future Directions

- Perform QA before treatment and during treatment
- Refine the QA analysis tools and apply in a robust manner
- Dose distributions comparison in patients
- Utilize the power of data

Dose Reconstruction Methods
**Novel QA Methods**

- Plan Dose Perturbation
- Fluence-Based Forward Algorithms
- 3D In Vivo Dosimetry
  - Time Resolved
- Machine Learning

---

**Plan Dose Perturbation**

- Difference between the measured and planned dose in phantom perturb the TPS calculated patient dose to create a corrected 3D dose distribution in patient.
- Forward calculation algorithm is not required. PDP uses measurements to create the perturbation matrix for correcting the plan dose.

---

**Forward Algorithms**

- Patient-specific beams are delivered to the detector typically in the absence of a phantom or patient.
- Planar measurements are corrected for the response of the detector and then used as the input fluence map.
- CT data along with a forward calculation algorithm is used to reconstruct the dose in patient.
- Requires an independent dose calculation platform but also can be performed using the TPS algorithm.
3D In Vivo Dosimetry
- EPID images collected during patient treatment are used to reconstruct dose in the patient.
- Measured transmission fluence corrected for EPID response and scatter from patient.
- Primary fluence is deconvolved, backprojected and then forward transported through the patient anatomy (CT or CBCT).
- 3D calculated patient dose compared with the treatment plan.

Lung Patient Tumor Shrinkage
- Analysis of VMAT at various time points does not suffer from the same geometrical shortcomings of planar integrated methods.
- Detect dose delivery deviations caused by patient anatomical changes.
- CT or CBCT and 2D planar pre-treatment dose, and plan parameters are used.

Time Resolved In Vivo Dosimetry
- Analysis of VMAT at various time points does not suffer from the same geometrical shortcomings of planar integrated methods.
- Detect dose delivery deviations caused by patient anatomical changes.
- CT or CBCT and 2D planar pre-treatment dose, and plan parameters are used.
**Time Resolved In Vivo Dosimetry**

- Control point (CP) by control point planar dose during treatment are compared to the CP-by-CP transit dose predictions based on planning CT.
- Provides dose comparison and the magnitude of gamma failure as function of gantry angle with the percentage $\gamma$ pixels $>+1$ or $<-1$.

---

**H&N Patient Weight Loss**

---

**Pelvic Patient**
Machine Learning Virtual QA

- Predict IMRT QA results using machine learning (ML).
- Characterize each plan by metrics that describe different aspects of plan complexity and may lead to dose differences.
- A regression algorithm is trained to learn the relation between the plan characteristics and each passing rate.

G. Valdes et al, Med Phys 2016, JACMP 2017

ML QA Results

- Metrics that described the passing rates with the higher the value of these metrics, the worse the passing rates
  - MU factor (MU per Gy)
  - Small aperture score and irregularity factor
  - Fraction of the plan delivered at the corners of a 40 × 40 cm field.

G. Valdes et al, Med Phys 2016

Conclusions

- Accurate and efficient QA methods that provide dose difference information in patients are becoming viable tools.
- In Vivo dosimetry QA ensures treatment delivery accuracy with respect to patient anatomy changes and setup errors.
- Time resolved QA for VMAT is a novel treatment monitoring tool due to its time-resolved measurement of dose delivery.
- While software-based QA tools are becoming more reliable, measurement will continue to be the gold standard.
Thank You