Patient-Specific QA: Challenges and Opportunities

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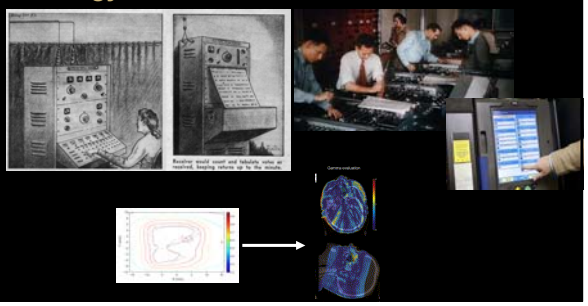
Technology and Methods Evolve

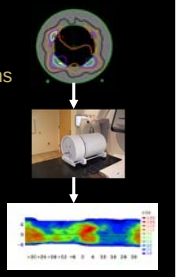


Patient-Specific QA Classification

- Measurement (most common and considered the gold standard)
  - ArcCheck, Delta4, Octivus, EPID….etc
- Computational
  - Logfile
  - MU checks
- Hybrid
  - Dose reconstruction

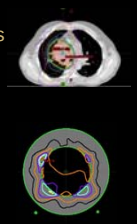
Patient-Specific QA: Current Paradigm

- 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.



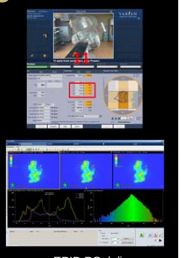
Patient-Specific QA: Challenges

- Phantom-based QA and patient dose distributions are different due to their differing geometries.
- Phantom QA plan does not check for errors arise 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



EPID PC delivery

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

CT

CT at Wk 3

QA Practice Future Directions

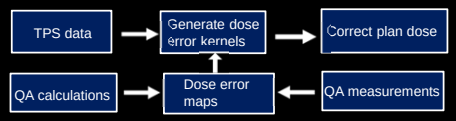
- Perform QA before treatment and during treatment
- Refine the QA analysis tools and apply in a robust manner
- Dose distributions comparison in patients
- Utilize the power of data

Dose Reconstruction Methods

Novel QA Methods

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

Plan Dose Perturbation



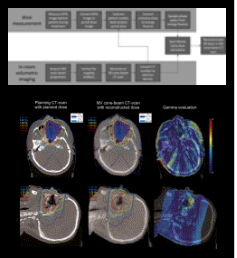
- Difference between the measured and planned dose in phantom perturb the TPS calculated patient dose to create a corrected 3D dose distribution in patient.
- Forward calculation algorithm is not required. PDP uses measurements to create the perturbation matrix for correcting the plan dose.

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 reconstruct the dose in patient.
- Requires an independent dose calculation platform but also can be performed using the TPS algorithm.

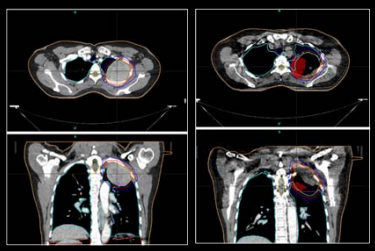
3D In Vivo Dosimetry

- 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 flounce is deconvolved, backprojected and then forward transported through the patient anatomy (CT or CBCT).
- 3D calculated patient dose compared with the treatment plan.



Wouter van Elmpt et al, IJROBP 2009

Lung Patient Tumor Shrinkage



CT CBCT at Wk 2

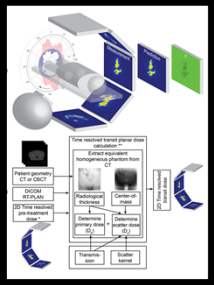
γ can be performed on organ-by-organ basis

Perfraction system results

Courtesy of Jennifer Hamilton

Time Resolved In Vivo Dosimetry

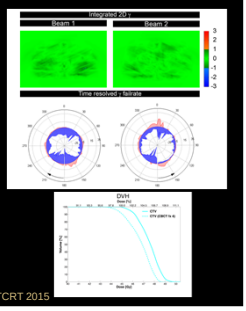
- Analysis of VMAT at various time points does not suffer from the same geometrical shortcomings of planar integrated methods.
- Detect dose delivery deviations caused by patient anatomical changes.
- CT or CBCT and 2D planar pre-treatment dose, and plan parameters are used.



LCG Persoon et al, TCRT 2015, M. Podesta et al, PMB 2014

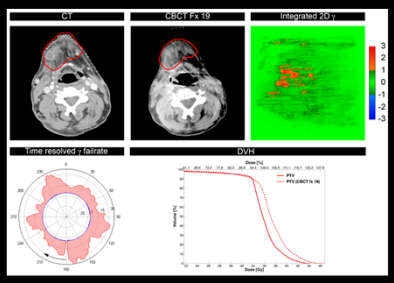
Time Resolved In Vivo Dosimetry

- 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 γ pixels >+1 or <-1.



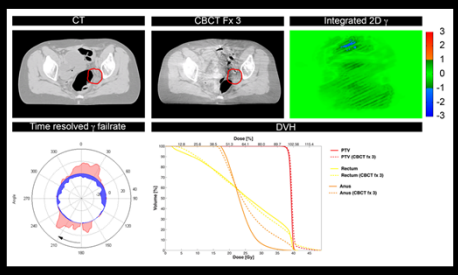
LCG Persoon et al, TCRT 2015

H&N Patient Weight Loss



LCG Persoon et al, TCRT 2015

Pelvic Patient



LCG Persoon et al, TCRT 2015

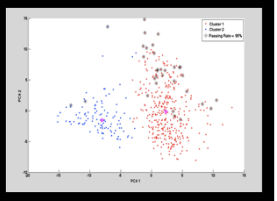
Machine Learning Virtual QA

- 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

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