Clinical Implementation of EPID-based Pre-Treatment and Transit Dosimetry QA Solutions

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Overview

- Necessary properties of an EPID dosimeter
- Commissioning
- Calibration
- Validation
- Routine QA for EPID based QA systems
- Action Levels
  - Pre-treatment QA
  - Transit Dosimetry.

Properties of a good Dosimeter

- Prior to purchasing a QA solution, one should confirm that the EPID panel will perform sufficiently well as a dosimeter.
- EPIDs equipped with modern Linacs perform suitably and have been well characterized.
- Older EPID panels may not be suitable for use with certain QA solutions.
- Important aspects of EPID performance
  - Robust and accurate positioning and re-positioning of panel
  - Robust and accurate EPID positioning with gantry rotation
  - Dose response linearity over a large range of MU settings
  - The EPID's response to different field sizes matches existing measurements
  - Panel Uniformity: the panel should exhibit a uniform response, excluding field edges and panel edges.
  - Dosimetric Reproducibility adjusted for Linac output should be stable.

Commissioning

- Commissioning of either a Pre-treatment QA or Transit Dosimetry solution should take place after both Linac commissioning and EPID panel commissioning for general imaging use (TG-58).
- The commissioning process is typically defined by the vendor and the user typically cannot significantly modify the process.
- Therefore, the user should be familiar with the performance and flexibility of a system before a solution is chosen or purchased.

The Commissioning Process

- General commissioning process
  - A series of vendor designed measurements are collected
  - These results from these measurements are imported into the vendor's software
  - The radiation properties of the Linac and the properties of the EPID panel are then modeled and the algorithm incorporates these properties to provide optimal results.
    - Field size effects, dose rate effects, scatter response, MLC transmission, dosimetric leaf gap, etc...
    - EPID ghosting, sag of the EPID panel at different gantry angles, backscatter radiation emanating from the support arm of the EPID system, etc…
  - Some vendor solutions have an extra calibration step
- The commissioning process is similar between Pre-treatment QA systems and Transit Dosimetry systems
  - Pretreatment QA systems measurements are collected in air
  - Transit Dosimetry measurements typically contain many measurements through a scattering medium
  - Typically, more fields are required to model transit dosimetry systems than pretreatment QA systems..

Calibration

- Many vendor solutions require a calibration procedure for the EPID panel.
- Typically, a set amount of monitor units is delivered to the EPID panel under reference conditions.
- This allows for the scaling of EPID panel output to match the expected LINAC output.
- Several measurements under different conditions may be needed so that a dose value can be assigned to the EPID signal generated.

Validation

- The validation tests should include a range of measurements to establish and verify the integrity of the system and establish performance baselines.
- The validation tests should encompass all energies, field sizes and dose rates.
- Validation of each modality should also be completed; step and shoot IMRT, sliding window IMRT, VMAT, SBRT, SRS, etc…
- It is recommended that the validation process include fields and plans utilized during the validation of the TPS to improve efficiency and for consistency.
- For the validation process the user should comprehend the EPID system's performance characteristics and limitations..

Daily and Annual QA for EPID based QA systems

- Daily QA
  - Follow TG58 and TG142
  - The QA tests that are outlined in these reports cover many aspects of both the Linac and EPID performance including
    - EPID positioning/repositioning
    - Imaging and treatment coordinate coincidence
    - Collision Interlocks
  - No additional QA steps should be necessary
- Monthly QA – We will review on the next slide
- Annual QA
  - TG53 and MPPG5a recommend that the dose calculation component of the QA system be tested annually or whenever a software upgrade occurs..

Monthly QA for EPID based QA systems

- Monthly QA tests for EPID based QA systems overlap significantly with TG-142.
- Some tests (i.e. EPID positioning) may be completed for TG-142 and does not need to be repeated when performing QA for Pretreatment-QA or Transit-Dosimetry systems.
- Other tests (Uniformity, Dose Constancy) may need to be repeated for each separate application
  - Imaging/patient alignment, Pre-Treatment QA and Transit Dosimetry

Monthly QA Tests Required

- 2D Pre-treatment QA
  - EPID positioning
  - Scaling
  - 2D Open Field Uniformity
  - Dose Constancy
  - IMRT Test Plan
  - VMAT test plan
- Transit Dosimetry
  - The same tests are required as with Pre-treatment QA
  - Many of these tests require a phantom on the couch
  - Tolerance levels are relaxed as compared to Pre-treatment QA systems..

Action Levels

- Error detection tolerances should be designed so they are sensitive enough to detect clinically meaningful errors while minimizing false positives and non-clinically relevant errors.
- One can implement the program with recommended tolerances and then after a sufficient number of cases evaluate whether the correct balance has been achieved.

  - <u>Action Levels to be discussed</u>
    - 2D Pretreatment QA
      - TG218 – i.e. > 95% of pixels passing 3%/2mm
    - 2D Transit Dosimetry
    - 3D Pretreatment QA
    - 3D Transit Dosimetry
    - DVH analysis

Action Levels - continued

- 2D Transit Dosimetry
  - Two principal modes of comparison and both use γ analysis.
    - Relative Mode or Absolute Dose Mode
  - For relative mode γ analysis, the passing criteria and tolerances reflect anatomic and setup variations from the baseline fraction versus subsequent fractions and is unrelated to TPS dose calculations.
  - For absolute mode γ analysis, the criteria may be looser due to uncertainties of dose conversion from EPID data.

Action Levels - continued

- 2D Transit Dosimetry Example

A study conducted in 2019 performed transit dosimetry analysis on a cohort of 57 patients with a total 855 fractions delivered consisting of 4079 fields. Each field was evaluated using 2D gamma analysis utilizing 3% and 3mm gamma criteria and a field was determined to have passed if >= 93% of the pixels passed the gamma analysis. It was found that almost **one-quarter** of the treated fields failed at least once during the course of radiation therapy.

Reference: Olch, A. J., K. O'Meara and K. K. Wong (2019). "First Report of the Clinical Use of a Commercial Automated System for Daily Patient QA Using EPID Exit Images." Adv Radiat Oncol 4(4): 722-728.

Action Levels - continued

- 3D Pretreatment QA
  - 3D pre-treatment dose can be calculated in the planning CT
    - Collect EPID images
    - Apply deconvolution kernel to recreate the exiting beam fluence
    - Calculate the 3D dose in the planning CT
  - These steps may increase uncertainty in the 3D dose calculation and should be quantified during commissioning.
  - Generally, the tolerances should be the same as for the standard 2D and 3D detector arrays, following TG-218 guidelines.

Action Levels – continued..

- 3D Transit Dosimetry
  - Utilizing transit images 3D dose reconstruction in the planning CT or CBCT can be completed using back-projection techniques.
  - 3D γ analysis as well as DVH comparisons to original plan can be performed.
  - It should be expected that the level of agreement that can be achieved with 3D back-projection should be less than with 2D analysis. *Mijnheer, et. al. 2015*
  - It is advised that the user evaluates achievable tolerances and understand that it is hard to correlate gamma passing rates dose errors in the patient.
  - Potentially DVH analysis may be more clinically meaningful. *Nelms, et. al. 2012*

- Mijnheer, B. J., P. Gonzalez, I. Olaciregui-Ruiz, R. A. Rozendaal, M. van Herk and A. Mans (2015). "Overview of 3-year experience with large-scale electronic portal imaging device-based 3-dimensional transit dosimetry." Practical Radiation Oncology **5**(6): E679-E687.
- Nelms, B. E., D. Opp, J. Robinson, T. K. Wolf, G. Zhang, E. Moros and V. Feygelman (2012). "VMAT QA: Measurement-guided 4D dose reconstruction on a patient." Medical Physics **39**(7): 4228-4238.

Action Levels - continued

- DVH Analysis
  - One approach is to utilize the same DVH evaluation metrics that were used during original plan approval but include an additional buffer.
  - Before implementation patient and plan specific tolerances to deviations for both PTVs and OARs should be established.
  - PTVs generally demonstrate better agreement than do OAR structures, especially if the plan is greatly sparing of the structure of interest. Wang et. al.
  - When the OAR dose approaches known safe tolerance limits, one should carefully consider what tolerances to implement for daily assessment.
  - Selecting adequate but relatively simple metrics for DVH based QA is an evolving process.
  - For daily PTV DVH analysis; the D98%, D95%, D90%, D2% are useful parameters to use for comparison;
  - For daily OAR DVH analysis; the mean, D1%, and maximum dose are often most relevant.

Pre-treatment QA and Transit Dosimetry Failures

- Pretreatment QA Failures
  - When pre-treatment QA fails, the same process for exploration of possible reasons for the failure as detailed in TG-218 can be followed.
    - Excluding phantom setup, since EPID pre-treatment QA is performed in-air.
- Transit Dosimetry QA Failures (*more complicated*)
  - For 2D gamma analysis correlation between the 2D error and the clinical relevance can be challenging
  - For DVH analysis, structure dose deviations are easier to interpret but considerations for contour accuracy and other uncertainties are necessary.
  - Regardless, if the magnitude of the error is clinically significant one should attempt to determine the reason(s) for the failure. *Olch, et. al. 2019*

Reference: Olch, A. J., K. O'Meara and K. K. Wong (2019). "First Report of the Clinical Use of a Commercial Automated System for Daily Patient QA Using EPID Exit Images." Adv Radiat Oncol 4(4): 722-728.

Questions ??

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