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.

- **Action Levels to be discussed**
  - 2D Pretreatment QA
    - TG218 – i.e. > 95% of pixels passing 3%/2mm
  - 2D Transit Dosimetry
  - 3D Pretreatment QA
  - 3D Transit Dosimetry
  - DVH analysis
• 2D Transit Dosimetry
  – Two principal modes of comparison and both use $\gamma$ analysis.
    • Relative Mode or Absolute Dose Mode
  – For relative mode $\gamma$ 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 $\gamma$ analysis, the criteria may be looser due to uncertainties of dose conversion from EPID data.
• 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.

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 $\gamma$ 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*

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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

Questions ??

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