Three Year Experience of Electronic Portal Image Device Based Daily QA for Photon Radiation Beams

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INTRODUCTION

Quality assurance (QA) program is set to verify beam dosimetry, mechanical accuracy and safety functions of linacs to ensure a safe and high quality radiation treatment. Balancing the thoroughness and efficiency, different levels of tests are performed daily, monthly and annually. As treatment delivery becomes more complex, more and more QA checks are added into the periodic QA tests. A more comprehensive QA program produces better quality control, but also increases the labor, time and cost required to accomplish the QA tasks. Among these QA tasks, daily linac dosimetry monitoring and image quality check are most essential to verify machine performance prior to treatment. Since the daily QA is often performed by morning radiation therapists, it demands a robust solution with high efficiency and less complicity while remain effective to catch any machine failures and report sub-optimal machine performance. Traditional daily QA approaches often rely on third party electronics with limited spatial resolution, complicated setup and high hardware/software cost. This process could be a huge burden to resource-thin centers and prevent a full implementation of TG-142. To tackle this problem, our previous work demonstrated that an EPID and on-board imaging (OBI) system based QA process have the potential to become an efficient, viable and easy-to-implement daily QA solution [1]. In this study, we evaluate the long term stability and robustness of this approach by describing our three-year's daily QA experience.

METHOD

An in-house designed phantom with two testing modules for kV and MV beams was used. The MV module was a $300 \times 300 \times 5\ mm^3$ water-equivalent plastic sheet with 12 multiple-thickness circular plugs – eleven of them made of steel were for transmission measurements and one solid-water block was used for imaging resolution test. The kV module was designed based on a Leeds phantom (TOR-18 FG phantom supplied by Varian) and used to test kV image quality. We measured 6MV, 10MV, 15MV, 6FFF, 10FFF photon beams and one kV X-ray beam on a Varian Truebeam Linac equipped with amorphous silicon (aSi-1000) EPID and OBI. As shown in Figure 1, during the test, the MV detector was programmed to be at 108 cm source to imager distance (SID) with gantry at 0 degree. The kV detector was at SID 150 cm with kV source at 270 degree. This system was commissioned as described in Ref [1] and the QA baseline was established for constancy check.

The daily QA delivery was be performed either through treatment management system or dicom plan file mode. The morning warm-up therapist inserted and locked the phantom into desired location, and visually verified its accurate alignment with light field and crosshair. Eight radiation fields were be delivered including one kV field, five MV open fields with a size of $22 \times 22\ cm^2$ and various energies, and two IMRT fields (one dynamic MLC and one step-and-shoot). After the delivery, acquired images were automatically saved to a network drive and therapists launch the web-based quality assurance information system to retrieve images and initiate the automated analysis by one button click. Finally, a daily QA report was prepared for physicist's approval with color-coded pass or fail of key parameters including dose output, flatness, symmetry, profile uniformity, TPR (20/10), field size, gamma passing rate of two IMRT fields, MV imaging resolution, kV imaging low and high contrast resolutions. This QA workflow was designed to be complete within 15 minutes.

Figure 1. Setup of EPID based Daily QA. The phantom is inserted and locked into the design position.

The data presented in this study tracks 3 years' daily QA executed in our clinic on each clinical day. QA metrics were reported in percentage difference deviated from baseline. MV and kV imaging qualities were evaluated base on the high and low contrast resolution. MLC performance was measured by calculating the Gamma (ref) passing rate against the baseline images. To further validate machine performance, the output deviations were also cross-compared with monthly QA measurements using ion chamber in a compact water phantom and TG-51 measurements with ADCL chambers.

RESULTS AND DISCUSSION

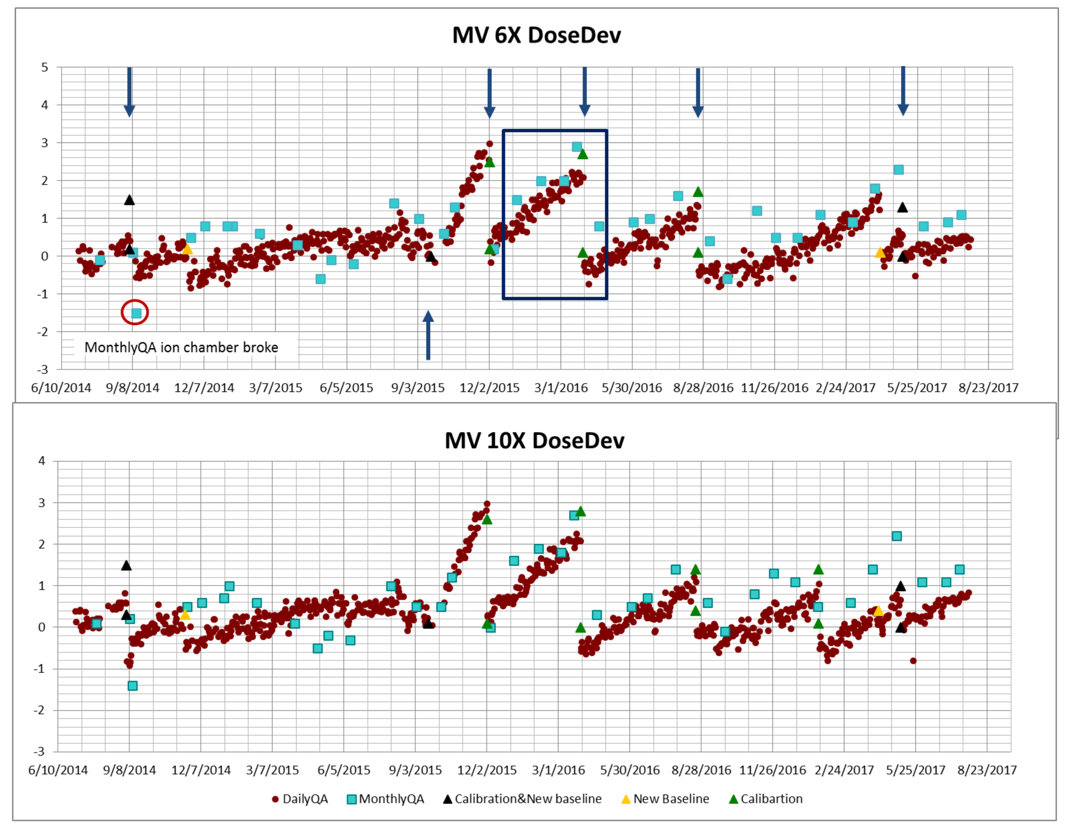

Figure 2 Trend of machine output in percentage difference comparing to baseline varying with time.

Output

Figure 2 displays the sample trends of 6MV and 10MV beams measured by EPID (show as red circles) along with monthly output QA measured with ion chamber (blue squares) and TG-51 calibrations (triangles) measurements. On 2015-09-19, a new machine monitoring chamber was installed so that later on dose output measurements were influenced and presented with higher growth speed than before. It was shown that machine output drifted continually until TG-51 calibrations was performed. The output from daily QA using EPID agrees with output from Monthly QA using ion chamber within 1.3%.

There are some discrepancy between monthly QA and daily QA output for some short time intervals, for instance, from May 2017 to July 2017 shown in Figure 2. There are two major factors contributed to the discrepancy: 1) in Monthly QA, ion chamber detector was manually placed on machine which brings set up difference from time to time; 2) Daily QA were always performed in the morning when machine was cold while monthly QA were often conducted after working hours when machine has been operated the whole day. Therefore, there was a potential discrepancy existing in machine output.

Profile Flatness, Symmetry and Uniformity

Beam profiles maintain considerably stable. Flatness deviation in both axial and transversal directions were within $\pm 1\%$; symmetry in both radial and transversal directions values from -1% to 1.5% and image uniformity changed between 0 and 0.8%. Positive drifts show up mainly in axial directional flatness, axial directional symmetry and in image uniformity in time stage from 2015-11 to 2016-08. Changes were only detected on specific dates, for instance on Annual QA. In Figure 3, three Annual QA dates involved and labeled as green vertical lines are 2014-09-04, 2015-09-19 and 2016-08-21, on which a new based was acquired or beam was steered. A short machine trouble-shooting period marked up in the blue box in Figure 3 from 2015-08 to early 2015-09 was due to software update and a series of consequence adjustments. Flatness, symmetry and uniformity reflected complex fluctuations during the time period.

Correlations between parameters are analyzed in paper [2] and conclusions are that dose output is not clearly correlated with other variables; transverse symmetry and flatness are positive correlated but axial symmetry and flatness are negative correlated. In our case only for flattened beams, symmetry and flatness in axial direction (Axsym and Axflat) are positive correlated (with Pearson coefficient 0.98 for 6MV); symmetry and flatness in transverse direction (Txsym and Txflat) are positive correlated (with Pearson coefficient 0.85 for 6X). Flatness in axial direction and uniformity are positive correlated (with Pearson coefficient 0.72 for 6X).

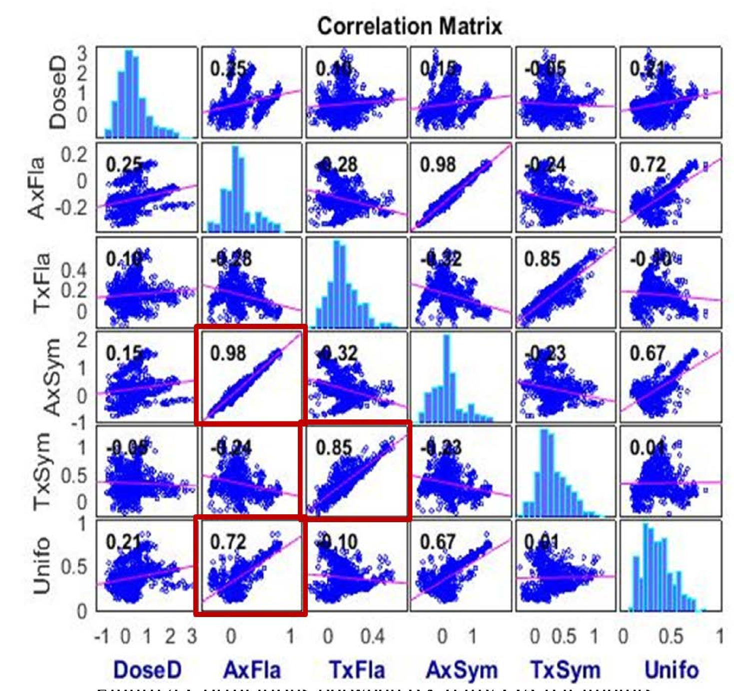

Figure 4 Correlations between 6X daily QA parameters

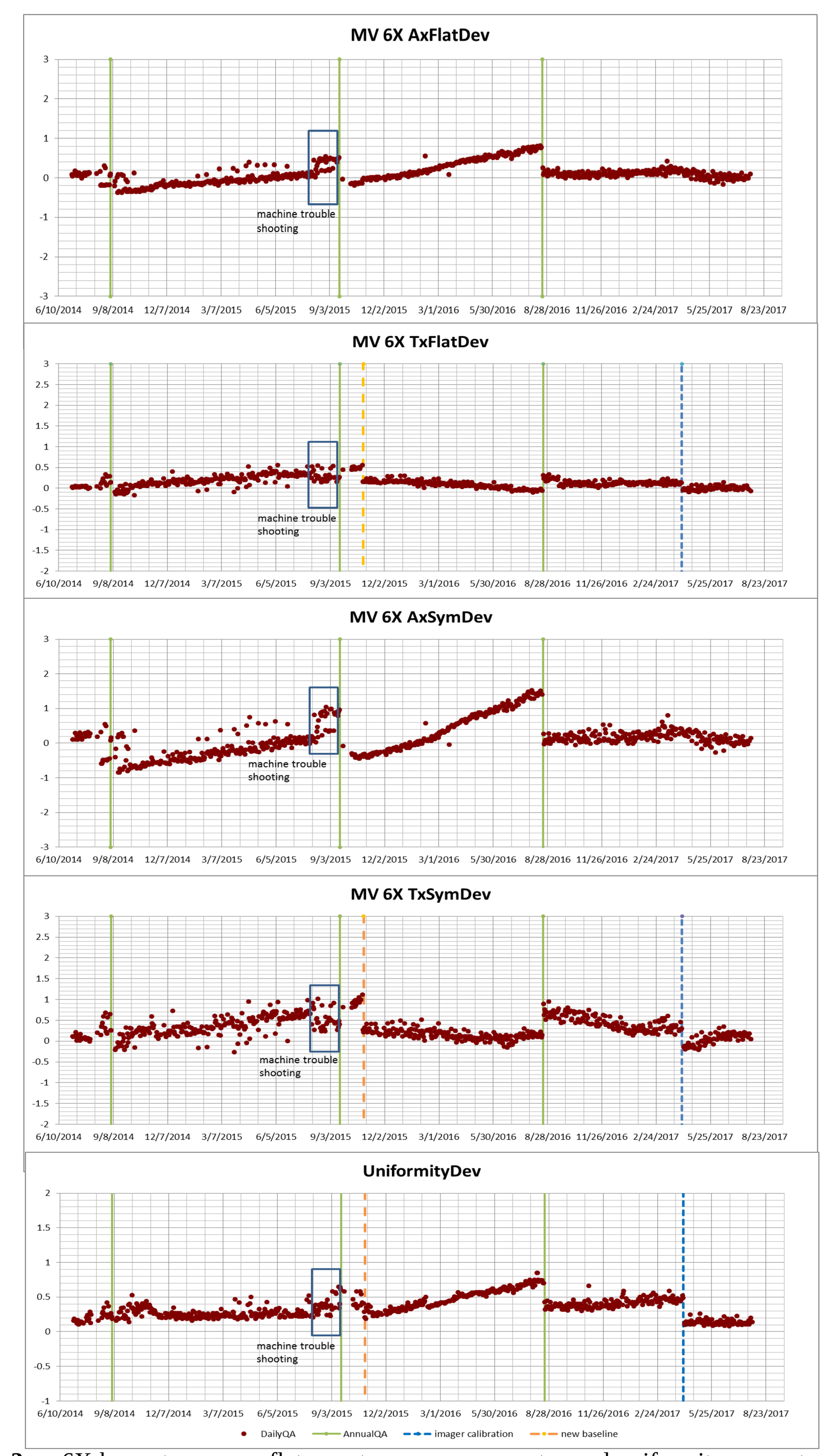

Figure 3. 6X beam traseverse flatness, traseverse symmetry and uniformity percentage difference (comparing with baseline) over 3 years. Daily QA results are plotted as red points and vertical lines represent activities we exceuted and related to visible Daily QA result trending shifts.

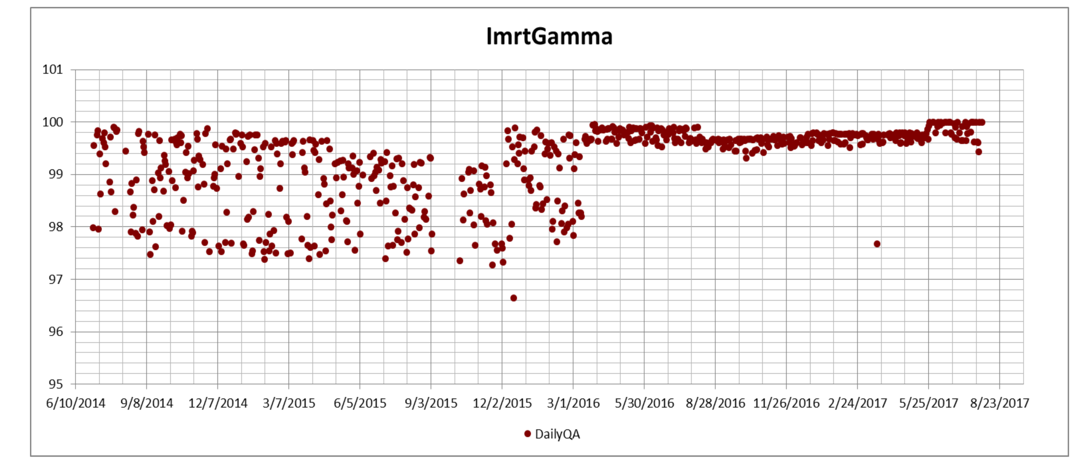

Figure 5. Trend of SS-IMRT Gamma passing rate.

IMRT field

IMRT tests including SS-IMRT and SW-IMRT have satisfactory passing rates, respectively above 97% and 95%. Gamma rates were not sensibly influenced by dosimetry changes. Figure 5 displays 6MV SS-IMRT field test results. Points before 2016-03 distributes in a wilder area between 97% and 100%, averaging at 98.8% and after which reduces to a narrow band between 99.2% and 100%, averaging at 99.7%. This is passing rate improvement related to a gamma criterion revision in IMRT test in 2016-03 from previous 1%/1mm to 2%/2mm mainly in consideration of efficiency.

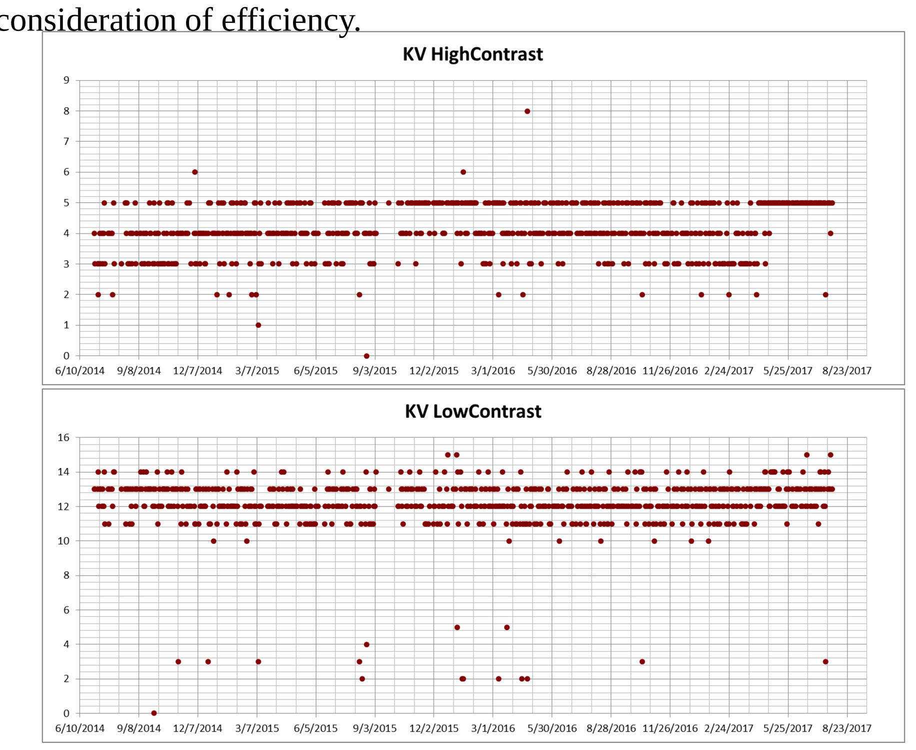

Figure 6. KV image quality.

Imaging quality test

96% of KV low contrast is above 11 and 98.4% of KV high contrast is above 3. KV contrasts are not influenced by calibrations. Failing points (below 11 and 3) are primarily because of detector un-shift error that leads to image cut-off and in consequence undermining image quality outcome.

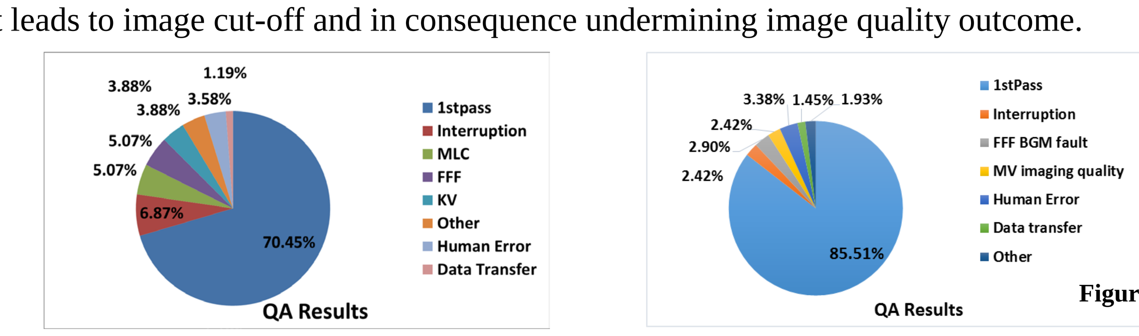

Figure 7. Process Improvement

Process improvement

The one-time pass rate is defined as the ratio of successful daily QA tests that completed in the first time of the day among all attempts summing up during monitoring period, excluding incidentals QAs. Comparing period 2014 -07-02 to 2015-12-10 with period 2016-10-03 to 2017-07-31, the one-time passing rate was improved from the first period 70.45% to the second period 85.51%. In the first period, the most frequent error was interruption which counts up to 6.87% of all QA tests. Following common problems are MCL, FFF, KV and 'other' errors. The biggest problem in the second period is human error, followed by FFF BGM fault, interruption and MV imaging quality errors. Visible reduction in interruption comes from our effort in retraining therapists. We also devoted to improving software and adjusting tolerance of IMRT tests to reduce dominate errors in 'other' category in the first period.

CONCLUSIONS

We described three year experience use EPID based daily QA for photon beams and visualized the long term trends.

Ref.

1. Sun. B.Z, et al., "Daily QA of linear accelerators using only EPID and OBI". Med Phys. 2015; 42(10): 5584-5594.
2. Chan. M.F, et al, "Visual Analysis of the Daily QA Results of Photon and Electron Beams of a Trilogy Linac over a Five-year Period". Int J Med Phys Clin Eng Radiat Oncol. 2015; 4(4): 290-299.

CONTACT INFORMATION

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