ArcCheck Assistants – Record automation during Patient Specific QA delivery for ArcCheck.

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Background

Patient Specific Quality Assurance (PSQA) for VMAT patients is required, according with GenesisCare policy. For VersaHD Elekta LINACs each plan is delivered using MOSAIQ OIS in QA mode over a Sun Nuclear ArcCheck detector (1) for 2D gamma index evaluation plus an absolute dose measurement on a pinpoint chamber inside the detector (2). The regular process is centralized in a single centre twice a week covering the patients from all VERSA sites across England.

The specific tasks for the measuring physicist prior the measurement include the Excel® database population with patients' demographics and expected point dose. During delivery, the total measured points and passing points, and the measured point dose are captured into the database. Finally, a patient specific PDF report is generated in SunNuclear software that it's uploaded into the OIS as well as the resulting files for each patient archived into the treating centre.

This process, although not difficult, can demand a long time for the physicist and had previously led to errors in the transcription process. Automation by Python (3) code for these tasks intends to improve the PSQA process efficiency while minimize the errors occurrences.

Methods

Python code with an associated GUI, named *AC Assistant* was created to automatize the data load before measurements and to automatically populate the gamma index passing ratio as well as complete the patient PSQA report with full demographics, and standardized information about the measured point dose, point dose difference and PSQA result following our internal policy. AC Assistant also allows to automatically back up the Excel database and archives the measurement data while push the PSQA report into the OIS.

We introduced these automations into our PSQA clinical pathway in January 2024, and the reduction in the required time for repetitive tasks in conjunction with the data consistency over 150 measured patients were assessed.

Results

Upon the implementation of the Assistants codes the required time to load the patients' information into the Excel database became negligible, being automatically performed under 60 seconds. AC Assistant code performs the PDF report completion and upload into OIS in less than 10 seconds per patient, moving the patient's data into the treating centre in less than 5 seconds. Considering 10 patients per session, our automation process saves 25 minutes on average.

Conclusion

Automation with the Assistant automation allowed PSQA measuring task simplification, keeping the required manual data entry to only the point dose value while allowing the physicist to focus on the data analysis process. Repetitive tasks are now automatically performed ensuring full data compliance. Further automation is projected by the application of PyiCom connection in future implementation.

KeyWords: PSQA, radiotherapy, VMAT, ArcCheck

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Analysis of Machine Performance Check Results to Plan Preventative Maintenance

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Background:

The Queen's Centre has four TrueBeam and two Halcyon Varian Linacs. Machine Performance Check (MPC) is Varian's integrated QA system and is required daily for the Halcyon. MPC has been used for all daily output consistency checks since October 2022. A weekly review of results is performed in lieu of consistency device measurements. This review consists of a qualitative examination of the weekly mean and range of output deviations. In January 2024 uniformity was added to the weekly review and a monthly geometry test review added to the routine Linac QA.

Processes:

Following every MPC test performance a text file is created containing the results for all individual tests. A script was written to pull the data to a spreadsheet, where graphs are created showing weekly mean and weekly range. Statistical Process Control methods were used to determine appropriate weekly range tolerances, based on historical data across all machines. Known exception data was excluded to keep the range tolerance representative of a healthy machine and be indicative of exception events.

Lessons Learned:

As the variation in results has no physical recommended tolerance, the primary method for initial investigation is comparison to other machines. Capability for direct comparison between machines has been added to subsequent versions of the review spreadsheet.
Currently the weekly range is based on a fixed calendar week. If a significant change occurs over a weekend, this would not be identified in the current range. It is planned to implement a rolling 7-day range to replace this parameter.

Best Practice:

Two key issues have been identified during this review process:

The MPC test X1 Position failed during daily QA due to a sudden shift in position of 1.4mm. On investigation it was determined that the X1 collimators were sticking on the support rods, effecting the primary and secondary positional readouts. Following corrective action, MPC reviewed identified smaller sudden jumps in position in the subsequent months. Further investigation and additional testing identified that the jaw crank assembly required replacement.

The MPC test Collimator Rotation Offset showed a sudden increase in variability. This variation was excessive compared to other machines but did not trigger the warning level of 0.45°. On investigation there was significant backlash in the collimator motor, and it is expected that a significant failure event would have occurred if not rectified. Following planned intervention, the variation in collimator rotation offset was significantly reduced in line with the other machines.

Conclusion

MPC tests a lot of machine parameters and is used daily for routine QA. Analysis of this data can identify exceptional behaviour long before test tolerances are breached, even though MPC geometry test tolerances are significantly more constrained than traditional tests as recommended in IPEM Report 81.

The review takes additional staff time and false positives would result in further time investigating normal function. This wasted time is reducing as staff become more familiar with performance.

Several major faults have been identified early allowing intervention to be carried out at planned times, rather than as emergency breakdown. This significantly reduces patient delays and staff stress. The collimator motor failure may have resulted in significant damage to the internal mechanisms had it not been identified early. This review is performed using existing data and does not require additional machine time.

R Moore, A Ionescu and QC team (Royal Marsden Hospital, SW3)

Background: MPC Data Explorer is a retrospective off-line assessment tool to examine regularly measured machine performance check (MPC) quantitative information having met criteria of performance (shaping by multileaf collimator within 1mm and dose consistency within 2% of expected). The approach used Varian's provided MPC subsystem that exports comma separated variable file format records (when requested by user) as input to an interactive python notebook (currently hosted on CoCalc www.cocalc.com).

Processes: Change Point Detection can be separated into two main parts: Anomaly Detection and Time Series Forecasting. Both contain pipelines that work in tandem. Anomaly Detection results from the first section play a key role in obtaining the appropriate datasets used for the Time Series Forecasting models of the later section. Secondly, the typical changes present in the MLCGroup time series are generally sudden vertical shifts in offset (Fig. 1), followed by a plateau of usually stationary evolution until the next shift occurs.

Dates of change The system attempts to locate likely dates of “change” and prints the line and the date estimated based on the smoothed data

This is intended to be a change of operating state rather than a transient jolt

Vertical lines:
Green; a change upwards
Red; a change downwards
Purple Line Smoothing Level: 2
This is an indication of the samples taken into the moving average superimposed on the initial MPC

Illustration of time sequence of "leaf offset" [mm] over years from 2015 to 2022

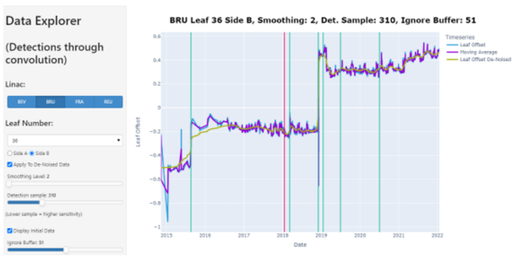

Fig. 3 – Changepoint detection results through convolution with a Heaviside step-function

Figure 1 Illustration with added identified step changes in same time sequence

Lessons Learned: Leave collaborative arrangements until proof of principle work is come to fruition. Include this possibility in framework and codebase but do not rely on data sharing. Identify the “Biggest risk” in the project objectively: ask “Verification of utility as added value information over native MPC - what does exploring the data add?”. Ensure the answer “Intercomparison with other performance data via summary metrics and visualisation gives medical physics experts reassurance” is true before it is believed.

Best Practice: Advanced time series are a valuable part of any scientific endeavour.

Conclusion: Overall thoughts - benefits/negatives of the project: The project stemmed from evaluation and commissioning of MPC and subsequent roll-out as a core front-line QC element, underwriting risk management and changing frequency of many separate calibration checks (dosimetry and geometry) due to this frequent integrated MPC test. As a result, the data harvest was feasibly placed to derive extra reliability data. The progress has found sufficient variation between the linac behaviours to make (statistical) modelling of interest and implied several approaches with increasing ‘generality’ but no clear discriminant ‘magic’. The next task is to establish what are useable as discriminants for trend and outlier identification. Then to correlate within and between the MPC and ‘other’ QC data. Risks to sharing / decision implications on machine availability and patient care are a competitive topic and strategic interest, which may become more relevant in the future healthservice. The system is so far useful if only to provide a “investigative” way to review offline collated data.

Automating Electron Density Calibration Checks with the RMI Phantom

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Background

The RMI phantom is a cylindrical solid water phantom consisting of 16 tissue-equivalent inserts. At University Hospitals Birmingham (UHB), it is used quarterly in CT quality assurance (QA) of different imaging protocols to assess the electron density calibration. These checks involve manually drawing circular regions of interest (ROIs) for each insert and then recording the mean Hounsfield units and associated standard deviations in QATrack+, which is a time-consuming task. In this project, a Python program was created to automatically detect ROIs, measure Hounsfield units and standard deviations, and then post the data for review via the QATrack+ API.

Processes

We first investigated whether OpenCV could detect circular ROIs using the Hough gradient method [1], finding the optimal parameters needed to accurately identify ROIs on the central slice of the phantom. Not all desired ROIs can be identified via this method due to contrast limitations, so we tested different imaging protocols to identify which ROIs were consistently detected. Using this, we created a mapping of all the ROIs relative to a specific insert. Pydicom was then used to calculate the Hounsfield units for each insert, comparing the data from the program to that which had been recorded manually. Finally, we tested whether data could be accurately sent to QATrack+ via the API.

Lessons Learned

If starting this project again now, we would consider how the parameterisation used in the Hough gradient method could be adjusted so that the program may be applied to other phantoms like the Catphan, which is used in routine linac imaging QA to assess CBCT image quality, and the Advanced Electron Density Phantom, which is routinely used to assess the kV imaging module of the Radixact at UHB. This highlights the necessity of considering a broader that meets the needs of an expanding service. It was also important to consider how the integrity of the program would be maintained, accounting for API checks in the risk assessment.

Best Practice

This project's biggest achievement is that it has considerably shortened a task that could take an hour to complete, enabling QA to be completed quickly and freeing up staff and machine time. It was also useful to discuss program requirements with end-users, which enabled us to implement key features such as slice selection from an early stage of development. The program is also very accurate; data agreed with manually recorded readings to within less than 1%.

Conclusion

Overall, the project has shown that it is possible to use existing Python modules like OpenCV to automate electron density calibration checks. It has made the CT QA workflow leaner, reducing the duration of a CT QA session by 25%. Moreover, the program can also be used for commissioning, which involves analysing 30 protocols at UHB. There is scope to expand the program so that it is compatible with similar phantoms used in routine imaging QA, enabling additional time savings for the QA of linacs and Tomotherapy units.

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In-House Development of Automated EPID-based Daily QA to Reduce QA Burden

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Background: Electronic portal imaging devices (EPID) are suitable for linear accelerator (linac) quality assurance (QA)[3,5] and can monitor linac performance over time. Current commercial products[1,6] can be manufacturer specific, use phantoms, or require online analysis. Here, we show in-house developed software for automated EPID-based daily QA without phantoms, with offline trend-analysis that enables a reduction in monthly QA given stable linac performance.

Methods: Daily images were acquired across 12 VersaHD linacs on IViewGT EPID panels between December 2023 and April 2024. Both flattening filter free (FFF) and flattened beams at 6 and 10 MV were used. Images were automatically exported and processed with in-house written software. Beam output, flatness, and symmetry results were stored in a database, and accessed through a webpage. Validation was performed against values recorded from monthly QA.

Results: The first prototype was developed by a small clinical team and finished within six months, with a predicted life-cycle of 15-18 months expected after long-term validation and tolerance development. Validation results (mean, standard deviation) across all beams and linacs were calculated for outputs (-0.01, 0.50 %), flatness (-1.17, 2.13 %), and symmetry (-0.13, 0.83 %).

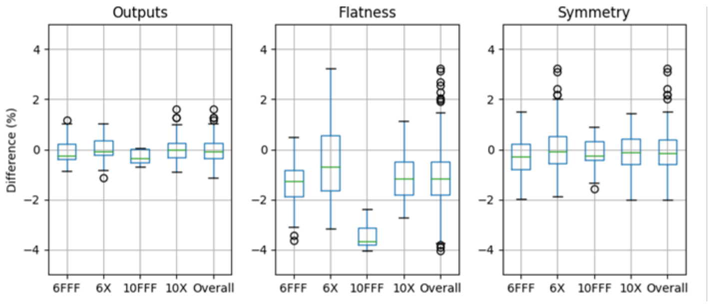

Figure 1: Validation results across all linacs. “Overall” is all beams combined. Outputs compared to ionisation chamber measurements. Flatness and symmetry results compared to 2D array measurements.

Due to panel saturation at full dose rate only 5 of 137 analysis images validated against monthly QA results were 10FFF.

Discussion: The development life-cycle has been comparable to procurement and commissioning of a commercial product. Output results are within the recommended constancy action limit[4]. Whereas, symmetry and flatness results have a broad range over the recommended monthly QA limit[4], and should only be used to monitor performance over time. FFF beam flatness results differed from flattened beams, which is potentially due to uncorrected panel response under FFF beams[2]. Long-term EPID panel stability monitoring and tolerance development is currently on-going, prior to clinical deployment.

Conclusion: The potential for in-house development where commercial solutions are not suitable has been demonstrated. Validation against commissioned QA devices shows the developed software performs adequately for use as a daily output constancy check, and for trend analysis of beam characteristics. Given stable linac performance this automated EPID-based QA approach provides a suitable evidence base to reduce monthly QA tasks.

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Experience of automated image analysis with PyLinac and QATrack+

Dan Kirby, PhD – Worcestershire Oncology Centre

Case study of experience no more than 1 page in Arial 11 point, presenting speaker underlined

Background. The Catphan504 phantom is used at WOC for monthly image quality QC of our Canon Acquilion LB CT scanner and 3 Elekta XVI CBCT systems. Analysis was done manually until the CT module of PyLinac in QAtrack+ v3.0 was commissioned.

Linac radiation isocentre analysis was previously done using the Flexmap calibration wizard in the XVI software, with only output of position and not diameter which is important especially for delivering SABR treatment accurately.

Processes. The PyLinac CT module output was utilised with custom coding in QATrack+ in such a way that the outputs required as per existing CT QA methods could be extracted. For instance, converting relative MTF to an effective no. of line pairs, and comparing HU for the various density inserts to baseline data for different CT protocols. CBCT image quality analysis was adapted to match the output used by Elekta acceptance tests (CAT) that are used for monthly QC.

The Winston Lutz module of PyLinac was implemented to calculate the position and size of the radiation isocentre for both gantry and collimator rotation for each of 6MV, 6FFF and 15MV beams. To make the delivery and analysis streamlined, a single step and shoot sequence comprised of 7 gantry angles (-180 to +180, every 60 degrees) and 6 collimator angles (again 60 degrees apart) was created as an EFS file and sent to the linac using Elekta iCom-CAT software.

For both Catphan and Winston-Lutz image analysis, a lightweight DICOM receiver (DMCTK) and batch script was configured to run on a local server PC to receive and zip the images to a location on a shared network drive for simple upload to QATrack+ by the user.

Lessons Learned: For the Catphan analysis, it was found artefacts can be present but not always detected by the software analysis as it only focuses on certain parts of the image. A human, visual inspection check was later added to the QA process to ensure such artefacts would still be detected.

Ensuring a backup manual method for analysis is still available/supported is important, as an XVI upgrade introduced a change to the catphan appearance which resulted in analysis to sometimes fail.

Best Practice: With some additional coding and process design, an automated solution is saving approximately 30-60 minutes of catphan analysis per month and the Winston-Lutz test gives assurance in the size of the radiation isocentre which was previously unknown (there were only mechanical isocentre checks previously) which was vital to support the rollout of SABR treatments.

Conclusion: The implmentation of PyLinac analysis in QATrack+ has saved physicist time for imaging QA and provided an efficient way to determine the position and size of the linac radiation isocentre.

SNC Machine for Linac QA

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At Exeter Oncology Centre we use SNC Machine for the majority of our routine linac QC: from Run-ups through to Monthly, Quarterly and Annual checks. Having most checks contained within a single platform accessible to Physicists, Engineers and Radiographers helps with training and collaborative working across the department, as well as the automated analysis tools creating significant time savings. We also currently use SNC machine for CT, HDR and TPS QC.

Our Daily Run-ups are performed by a mix of staff members and comprise Safety checks, a Daily Match and Shift, Field size and laser checks as well as automated output and geometry checks via MPC. Additional weekly tasks appear only on their scheduled day, such as Daily QA3 measurements of output, energy, field size, flatness and symmetry.

Monthly and Quarterly QC is performed by a mix of Physicists and Engineers and the checks run through SNC include Geometry, Flatness and Symmetry, Image Quality, Image Geometry, MLC, Field Size and Winston-Lutz. Annual checks such as Electron Output Factors and kV Tube Performance are also contained within the SNC platform.

Automated image analysis is used for MLC Picket Fences, Field Size images, 2D and 3D Image Quality tests and Winston Lutz images. All results can be easily reviewed and trended in order to identify issues and patterns or to review tolerance levels. We do maintain a separate checklist document outside of SNC showing the required QC on each linac for any given month, which is initialled to indicate completion and review of the required checks.

The next update of the software to version 4.3 will introduce Asset Management enabling us to include Dosimetry measurements, which are the largest group of checks not currently performed using SNC.

Most of our templates have been designed in-house, either from scratch or adapted from the many standardised templates available within the platform. The use of automated analysis protocols can limit the adaptability of the templates; care has to be taken when making changes to templates as these can cause Baselines to be lost or reset. Each linac requires its own set of templates so there has to be consideration around how these are generated and maintained, in order to ensure they are consistent and up-to-date. We have recently overhauled this process and how we integrate use of the platform into our Quality System.