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# Machine Performance Check (MPC) Beam Consistency Checks for 3 TrueBeam Linac in Different Centers

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## Abstract:

**Aim**: The aim of this study is to evaluate the constancy of the TB MPC over a long period of time, as well as to compare the performance of multiple TB MPC systems across different centers.

**Methods**: The TB MPC system was run daily at morning run-up on each Machine. The parameters tested by the MPC system and the corresponding tolerances are compared to the daily QA reports and the ionization chamber output. The results were statistically evaluated.

**Results**: the % difference in 6 MV output as measured by the TB MPC system compared with the corresponding monthly ionization chamber measurement on the 3 Linacs from January 2017 to November 2022. The maximum difference was 2%. The difference was also within 2% in consistency for the 3 TB Linacs. The rate of failure to detect any misalignment or output change for all other parameters was 0.1% or less.

**Conclusion**: our measurement indicates that MPC is appropriate as a daily output constancy check. There were a non-significant number of false negative results reported by MPC, and we would advocate the use of independent methods, such as the use of the Daily QA device, to quickly resolve these when they occur.

**Keywords:** MPC, QA TrueBeam, Daily check, Output check

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## Introduction:

The clinical goal of radiotherapy is to deliver a high dose of radiation to the tumor while minimizing the dose to surrounding healthy tissues. A comprehensive quality assurance (QA) is essential for the safe and effective delivery of radiotherapy. A comprehensive QA system helps ensure that the treatment plan is accurate and that the radiation is delivered as intended. A good QA program involves a combination of measures, including equipment calibration, patient positioning verification, dose measurement and validation, and overall treatment plan verification. QA systems can also help identify potential errors or problems before treatment begins. For example, during the planning stage, QA can help ensure that the dose is being delivered to the correct location and that the treatment plan is optimized for each individual patient. During the treatment delivery, QA can help ensure that the radiation is being delivered according to the plan and that the patient is properly positioned. With the introduction of advanced techniques, such as modulated techniques, hypofractionation, and FFF (flattening filter-free) beams, the need for comprehensive QA programs is even more critical. Hypofractionation involves delivering a higher dose of radiation over a shorter period of time than traditional fractionation. Furthermore, advanced techniques like intensity-modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT) require more complex treatment plans and delivery techniques, which can also increase the potential for errors. This can increase the effectiveness of the treatment but also increases the risk of side effects if the treatment is not delivered accurately. Therefore, QA programs are essential to ensure that the treatment is delivered safely and effectively. Checking the coincidence of all the isocenters is an essential part of the QA program for a modern Linac system. The isocenter is a geometrical point in space that is the intersection of linac axes of rotation around which the radiation beam rotates during treatment delivery. The accuracy of the isocenter's location is critical to delivering the intended dose to the tumor while minimizing the dose to surrounding healthy tissue. The MV electronic portal imaging device (EPID) and kV onboard imager (OBI) are imaging systems that can acquire pre-treatment images, to verify the patient's position and the accuracy of the treatment plan and to verify the isocenter's accuracy. The MV EPID is capable of acquiring images during treatment delivery, while the kV OBI can acquire images before treatment delivery, including cone-beam CT (CBCT) images. During the QA program, the isocenters for the MV EPID and kV OBI systems should be verified to ensure that they coincide with Linac's mechanical isocenter. This involves comparing the isocenters' locations using a phantom or other reference object and verifying that they are all aligned within a specified tolerance. The Machine Performance Check (MPC) application is a tool developed by Varian Medical Systems for its TrueBeam 2.0 platform. It is designed to perform a comprehensive quality assurance check of the machine's performance, including the Onboard Imager (OBI) system. The MPC application is a software program that runs on the TrueBeam 2.0 platform and is used to check the machine's imaging and radiation delivery performance. The MPC application uses a series of tests to verify the machine's performance, including image quality, image registration accuracy, mechanical positioning for moving parts in the machine, and radiation beam output. The accuracy of the MPC tests was established within the tolerances suggested by TG142. The tests are designed to ensure that the machine is performing within specified tolerances and that the imaging and radiation delivery systems are functioning properly. If the tests indicate that the machine is not performing within acceptable limits, corrective action may be required, such as recalibration of the machine or other adjustments. There have been several studies examining the consistency of TrueBeam® systems in delivering radiation therapy. These studies typically focus on evaluating the variation in beam output data over time to ensure that the system is operating within established tolerances.

The aim of this study is to evaluate the constancy of the TB MPC over a long period of time, as well as to compare the performance of multiple TB MPC systems across different centers. Evaluating the constancy of the TB MPC over time is important to ensure that the system continues to deliver precise and accurate radiation doses to cancer patients. This requires regular quality assurance testing to monitor the system's output and ensure that it remains within established tolerance limits. Comparing the performance of multiple TB MPC systems across different centers can also be valuable in identifying any variations in performance that may exist between systems or facilities. This can help to inform best practices for quality assurance and ensure that all patients receive the same high level of care, regardless of where they receive treatment.

## Patients and Methods:

*MPC and Conventional QC*

The TB MPC system was run daily at morning run-up on each of the three Varian TrueBeams in three different centers. All Linacs were equipped with the aS1200 portal imager, with the TrueBeams equipped with Millennium 120 MLC. All Linacs were capable of delivering 6 and 10 MV and flattened photon beams, and 6, 9, 12, 16, and 18 MeV electron beams. In addition to the daily use of the TB MPC system, weekly measurements were performed on all beams using the DailyQA3 device from Sun Nuclear Corporation, which utilized a number of ionization chambers and diode detectors to measure output constancy, flatness, symmetry, energy, and radiation field size.

The parameters tested by the MPC system and the corresponding tolerances are outlined in Table1. The beam measurements were acquired for all beam energies, with Geometry tests performed for 6 MV only. The methods employed by the MPC system to measure the various beam and geometric parameters can be found in published literature. In some cases, MPC measurements were not completed due to interlocks during the imaging sequence or other technical issues. However, all available results were included in the analysis.

The institutional QC program tests of AAPM TG 142 were recorded. The conventional QC tests and tolerances are also listed in Table 1. The whole QA test was performed monthly.

Table 1: Conventional QC tests and tolerances

| MPC test group | Thresholds | Routine QC test |
|---|---|---|
| **Isocenter** | ± 0.5 mm | film |
| **Collimation** | 2 mm | film |
| **MLC Reproducibility** | 1 mm | Picket fence test in portal image |
| **Jaws** | 1 mm | film |
| **Gantry** | 0.5° | Mechanical test |
| **Beam Output Change** | 2% | Ionization chamber |
| **Beam Uniformity Change** | 2% | flatness and symmetry |
| **Beam Center Shift** | 0.5 mm | flatness and symmetry |

*Output constancy*

The output of the system was measured monthly using ionization chambers to evaluate the accuracy and consistency of the TB MPC system, The ionization chamber output was then compared with the corresponding MPC output for each beam on all Linacs from January 2017 to November 2022. The % difference between the ionization chamber output and the MPC output was calculated, with the ionization chamber output serving as the reference value. Photon outputs were measured using a Farmer ionization chamber, while electron outputs were measured using a Markus chamber, which was all calibrated. To ensure the accuracy and stability of the measurement equipment, the annual field chamber calibrations were conducted to demonstrate that the absorbed dose to water calibration factors was stable within 0.5% for each chamber. This helps to ensure that any differences observed between the ionization chamber output and the MPC output are due to differences in the performance of the TB MPC system, rather than variability in the measurement equipment.

*Analysis of MPC records*

To investigate a potential failure, the system is subjected to either a DailyQA3 measurement or a corresponding monthly conventional QC test. If the TB MPC system detects an out-of-tolerance parameter during the test, this is considered a positive result.

To determine whether the out-of-tolerance result is a true or false positive, the result is compared to the corresponding result from the conventional QC test. If the conventional QC test confirms the out-of-tolerance result, this is considered a true positive. However, if the conventional QC test does not confirm the out-of-tolerance result, this is considered a false positive.

The use of both DailyQA3 measurements and conventional QC tests helps to ensure that any potential failures in the TB MPC system are identified and addressed promptly, while minimizing the risk of false positives or false negatives. By using both methods together, healthcare providers can have greater confidence in the accuracy and reliability of the TB MPC system, which can help to improve patient outcomes and safety.

## Results:

*Output measurements*

Figure 1 illustrates the % difference in 6 MV output as measured by the TB MPC system compared with the corresponding monthly ionization chamber measurement on the 3 Linacs from January 2017 to November 2022. The results for 6 MV are representative of all beam energies. The maximum difference observed was 2%. These results have been corrected for each new baseline of the MPC system, and the % difference is normalized to zero for the first measurement on each Linac. This allows for a more accurate comparison of the TB MPC system's performance over time and across different Linacs.

Table 2 provides the % difference in output as measured by the TB MPC and a comprehensive overview of the performance of the TB MPC system across all beam energies. By comparing the MPC output to the reference ionization chamber measurement, we can ensure that the TB MPC system is delivering an accurate dose.

*Analysis of MPC reports.*

There were a few instances of MPC test failures during this time period, which denotes that the TrueBeam Linacs were stable. The highest rate of failure for any MPC test was 0.4% for the Beam Output Change test, and the Beam Center Shift test was 0.4% for. The rate of failure for all other parameters was 0.1% or less.

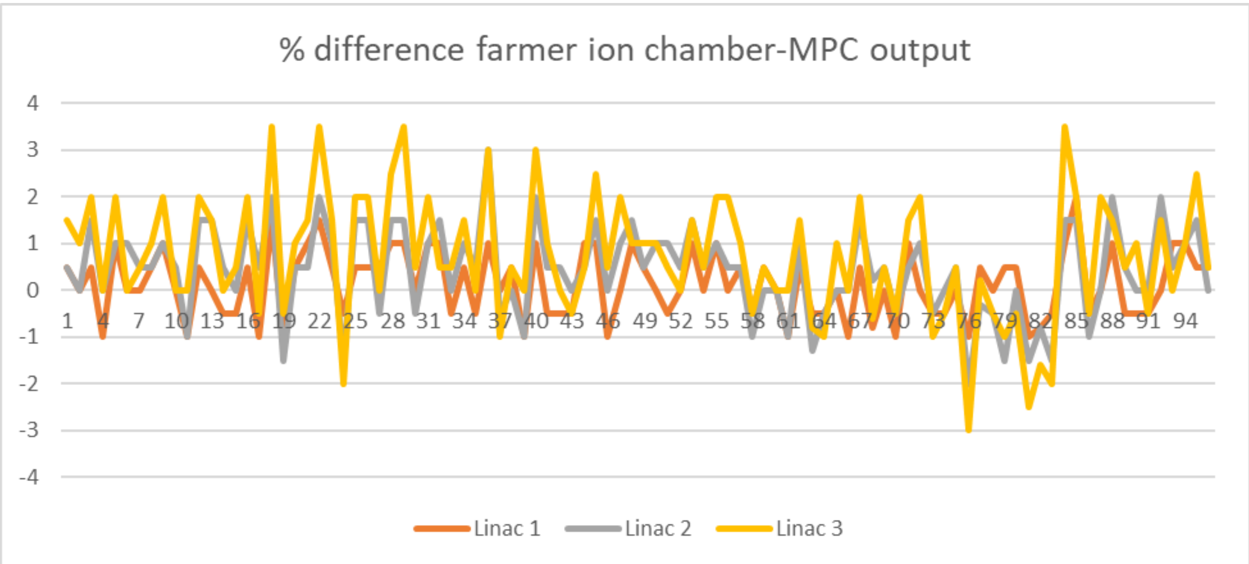


Figure 1: the % difference in 6 MV output as measured by the TB MPC system compared with the corresponding monthly ionization chamber measurement on the 3 Linacs

Table 2: The % difference in output as measured by the TB MPC

| Beam | Number of measurements | Mean % difference | Min % difference | Max % difference |
|---|---|---|---|---|
| **6 MV** | 288 | 0.1 | -1 | 2 |
| **10 MV** | 288 | 0.3 | -2 | 2 |
| **6 MeV** | 288 | .4 | -2 | 2.5 |

## Discussion:

These results in Figure 1 suggest that the TB MPC system is performing within acceptable tolerance limits, with only small differences observed between the MPC output and the reference ionization chamber measurement. However, the differences observed between linacs indicate highlights the importance of regular quality assurance testing to identify and address any potential issues, and to ensure that all patients receive safe and effective radiation therapy, regardless of which Linac they are treated on.

The agreement between the MPC and ionization chamber measurements was found to be good, with 98.8% of all measurements within 1%.

Although the reduced consistency in the MPC-ionization chamber agreement for any measured energy was considered acceptable, it may be due to the inherent instability of this beam energy, which requires more regular tuning by engineers to maintain a stable dose rate. These findings highlight the importance of regular quality assurance testing to identify and address any potential issues or variability in the performance of the TB MPC system. By monitoring the agreement between the MPC and ionization chamber measurements,

Table 2 By comparing the MPC output to the reference ionization chamber measurement, healthcare providers can ensure that the TB MPC system is delivering safe and effective radiation therapy to cancer patients. Overall, the availability of this summary table is a valuable resource for healthcare providers and can help to inform ongoing efforts to improve the accuracy and consistency of radiation therapy for cancer patients. Overall, the availability of this summary table is a valuable resource for healthcare providers and can help to inform ongoing efforts to improve the accuracy and consistency of radiation therapy for cancer patients.

Our data revealed an increase in output of between 5-6% per year for the three Linacs over the 8 years. Our finding is in agreement with in concept of output increase with (1).

(2) suggest an increase of 3% per year for 6 MV output measured with an ionization chamber for the TrueBeam, which is consistent with the findings reported in the literature for previous Varian Linac models. For example, (3) reports an increase in output of 2-4% per year on 1 Trilogy and 2 iX Varian Linacs, and (4) reports an increase in output of 3% per year for the Varian 2100C/D accelerator over the first 4 years of use, followed by a decrease of 0.4% per year for the next 3 years. These findings highlight the importance of regular quality assurance testing to monitor the output of the Linacs and ensure that they are delivering safe and effective radiation therapy.

The results of failure revealed insights into the performance of the Varian of the MPC system in detecting any potential issues or deviations from established tolerance limits and baseline.

## Conclusion:

The variation in output as measured by MPC versus ionization chamber measurement indicates that MPC is appropriate as a daily output constancy check, but cannot replace monthly ionization chamber output measurements. There were a non-significant number of false negative results reported by MPC, and we would advocate the use of independent methods, such as the use of the Daily QA device, to quickly resolve these when they occur.

As potential further work to this study, the step for evaluation of MPC could be the ability of MPC to Predict failure.

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