TURKISH JOURNAL of ONCOLOGY

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

ORIGINAL ARTICLE

A Phantom-free Approach to Patient-specific Quality Assurance for RapidArc Treatment Delivery

Sumanta MANNA,[1,2] Benoy Kumar SINGH,[1] K Joseph MARIA DAS[3]

[1]Department of Physics, GLA University, Mathura-*India*
[2]Department of Medical Physics, Kalyan Singh Super Specialty Cancer Institute, Lucknow-*India*
[3]Department of Radiotherapy, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow-*India*

OBJECTIVE

The complexities associated with RapidArc in treatment planning and delivery have always required pre-treatment quality assurance (PSQA). This study aimed to compare the PSQA results of FractionLab, a phantom-free log file analysis, with 2D array and portal dosimetry (PD) to evaluate appropriate gamma criteria.

METHODS

Thirty treatment plans each from Head and Neck (H&N) and pelvis sites were analyzed. FractionLab (Varian/Mobius Medical System) was used for phantom-free gamma analysis of delivered and planned fluences based on log files. PD was performed using an aS1200 EPID, and 3D gamma analysis was conducted using the Octavius 4D 1500 2D detector array. Gamma evaluation in FractionLab was performed using log files from 0.1%/0.1 mm to 1%/1 mm in increments of 0.1%/0.1 mm and compared with global gamma criteria.

RESULTS

The average gamma passing rates for H&N and pelvis sites using portal dosimetry, the 2D array (3%/2 mm), and FractionLab were 98.68% and 98.17%; 96.79% and 98.79%; 98.31% and 98.02% at 0.5%/0.5 mm, respectively. The portal dosimetry results (3%/2 mm) were statistically comparable with FractionLab (0.4%/0.4 mm–0.7%/0.7 mm).

CONCLUSION

This study demonstrated the performance and suitability of gamma criteria for FractionLab in a phantom-free PSQA settingand it can serve as a reliable second check for PSQA.

Keywords: 2D-array; FractionLab; log files; portal dosimetry; PSQA; radiotherapy.

INTRODUCTION

In radiotherapy, the goal is to deliver the precise radiation dose to the target while minimizing damage to the surrounding normal tissues. The development of modern, high-precision radiotherapy techniques such as Intensity Modulated Radiotherapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) necessitates an accurate validation program before clinical implementation. Therefore, a comprehensive quality assurance (QA) program is essential to ensure the proper functioning of all components in the radiotherapy treatment planning and delivery process. In addition to these QA programs, separate verification is required for patient treatments,

Received: September 12, 2024
Revised: December 03, 2024
Accepted: December 11, 2024
Online: June 02, 2025

Accessible online at:
www.onkder.org

Dr. Sumanta MANNA
Department of Physics, GLA University,
Mathura-India;
Department of Medical Physics,
Kalyan Singh Super Specialty Cancer Institute,
Lucknow-India;
E-mail: sumanta7915@gmail.com

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

often including additional pre-treatment verification checks for individual patients.[1,2] The current standard practice in Patient-Specific Quality Assurance (PSQA) employs a measurement-based approach, including point dose measurements and planar dosimetry.[3]

Point dosimeters, typically cylindrical ionization chambers, possess desirable dosimetric properties such as dose and dose rate linearity, stability, directional independence, and energy independence.[4] These characteristics make them the preferred choice for obtaining point-dose estimations. However, these detectors are sensitive to positional errors and volume-averaging effects, particularly in high-gradient regions.[5] Planar dose measurements employ array detectors and portal imagers, which provide two-dimensional (2D) dose distributions. Array detectors are clinically accepted for their convenience and efficiency, although the spatial resolution of isodose distributions depends on detector spacing.[6] In contrast, the portal imager, or electronic portal imaging device (EPID), offers high-resolution fluence-based data due to its amorphous silicon (a-Si) material composition.[7]

PSQA ensures the accuracy and safety of the radiotherapy treatment process. The most common method for quantitative comparison is gamma analysis, which combines dose difference (DD) and distance to agreement (DTA) criteria.[8] Typically, phantom-based PSQA is performed before actual treatment delivery. Generally, homogeneous materials, which do not account for patient-specific anatomy and heterogeneity, are used in measurements. Additionally, setup uncertainties during the alignment of independent detectors can impact measurement accuracy.[9] Furthermore, there is a limitation in identifying alterations and errors in dose delivery that may occur during treatment delivery. Therefore, real-time dose verification is essential for intensity-modulated treatment delivery.[10,11]

Adaptive radiotherapy, while a promising advancement in personalized cancer treatment, faces significant challenges with traditional phantom-based quality assurance (QA).[12] The process of phantom-based QA is labour and time-intensive. Furthermore, integrated dose measurements do not easily separate the root causes of errors. Therefore, to overcome these limitations, more sophisticated and efficient QA methods must be used to ensure the effectiveness of routine and adaptive radiotherapy.

Recently, FractionLab (Varian/Mobius Medical System, Houston, TX, USA) introduced a gamma index analysis method for comparing planned and delivered fluences using trajectory log files, eliminating the need for a phantom.[13] The trajectory log files automatically track a wide range of parameters, recording 130 variables during treatment and comparing real-time measurements to the predetermined treatment plan, with samples taken every 20 ms.[14] Previous research has shown that trajectory log file analysis is useful for determining treatment efficacy.[15] FractionLab automatically processes trajectory log files generated by a medical linear accelerator, allowing for batch analysis and assessment of various performance metrics, such as MLC positioning errors, beam shutoff speed, and planned/delivered gamma agreement. Despite its potential, the clinical performance of FractionLab has not been previously reported. Therefore, the current study aims to compare the clinical performance of FractionLab with portal dosimetry, a commonly used tool for patient-specific QA in intensity-modulated treatment delivery. Additionally, we aim to determine an appropriate gamma index for patient-specific QA using FractionLab.

This study aims to elucidate the dosimetric performance of FractionLab-based logfile analysis and compare it with the QA results of the EPID (aS1200; Varian Medical Systems, Palo Alto, CA, USA) and Octavius 4D (PTW Freiburg GmbH, Freiburg, Germany), which are conventionally used for patient-specific quality assurance.

MATERIALS AND METHODS

Study Design

This study encompasses a cohort of thirty treatment verification plans from head and neck (H&N) and pelvis sites. All treatment plans were generated using the RapidArc technique and delivered using the TrueBeam SVC system (Varian Medical System, Palo Alto, CA). The inclusion of the H&N and pelvic regions ensures a diverse representation across different anatomical sites and encompasses different complexities in treatment planning and delivery.

Treatment Planning and Delivery Techniques

All RapidArc plans were created using the Eclipse treatment planning system (v15.6; Varian Medical Systems, Palo Alto, CA, USA) with dual-arc with jaw tracking using a 6MV flattened photon beam. A photon optimizer (PO; Version 15.6.06, Varian Medical Systems) was selected for inverse optimization based on physical and biological objectives. Hence, the physical constraints of the upper, lower, and mean objectives were used to limit the dose level in a defined portion of the structure volume, to define the minimum dose level

that a particular target volume should receive, and to define the mean dose that should not be exceeded for the structure, respectively. Dose computations for each planned dose set were computed using the AAA algorithm (Version 15.6.06, Varian Medical System) with a 2.5-mm dose grid resolution. All RapidArc plans were delivered using a Varian TrueBeam accelerator equipped with a 120-leaf Millennium multi-leaf collimator (MLC), capable of delivering 6MV FF photon beams with a maximum dose rate of 600 MU/min.

MLC Log Files

The log file recording modes are active in TrueBeam, unlike previous C-series accelerators (such as Trilogy, EX, and iX). Therefore, there is no delay in positioning the leaves due to the efficient design of the active MLC controller, which distinguished TrueBeam from its predecessors. Therefore, the leaves move promptly to their planned positions without any delay. The log files generated by TrueBeam, known as Trajectory logs, are binary files that record both the planned and actual positions of the MLCs. These logs are captured at a sampling rate of 50 Hz (20 ms).

FractionLab

The FractionLab software analyzes MLC positioning errors, beam shutoff speed, and planned and delivered gamma agreement using the machine log files, hence the trajectory log files generated by linear accelerators. The trajectory log files include the delivered MLC position information as a function of the fractional dose, which FractionLab uses to create fluence maps magnified on the iso-centre plane. These fluence maps are generated at a fixed resolution of 0.5 mm per pixel. Two files ('A' bank and 'B' bank) were created for the trajectory log files of a field. The trajectory log files were used in this study using FractionLab software for analysis. The general parameter specifications are as follows: sampling time=0.05 sec, MLC position=0.01 mm, jaw position=0.1 cm, and gantry angle=0.1°; the couch angle is not reflected in the log files.

Therefore, the trajectory log files are used in FractionLab to perform the gamma evaluation between the automatically calculated 2D fluence and the 2D fluence generated using the log files after irradiation for the first treatment fraction. The gamma criteria were used in FractionLab by varying the DD/ DTA values from 0.1%/0.1 mm to 1%/1 mm.

Electronic Portal Imaging Device

Portal dosimetry (PD) was used to evaluate the measured fluence using the EPID attached to the Varian Truebeam (Varian Medical Systems, Palo Alto, CA, United States) linear accelerator, which is equipped with an amorphas-Si 1200 EPID. The A-Si EPID has a maximum irradiation area measuring 43×43 cm^2, accompanied by a pixel dimension of 1280×1280 pixels and detects a size of 40×40 cm^2, yielding a pixel size of 0.34mm.[16] Portal dosimetry is extensively applied for patient-specific QA in complex radiotherapy such as IMRT and RapidArc. In the current study, a gamma analysis was done for the comparison of planned vs delivered fluence using enhanced gamma criteria with DD/ DTA values of 3%/3 mm, 3%/2 mm, 2 mm/3% and 2%/2 mm with a global and local gamma criterion for H&N and pelvis site.

Octavius 4D with 2D Detector Array

Each plan was recalculated on the OCTAVIUS phantom with the same parameters and AAA algorithm to generate the patient-specific verification plan. The Verisoft (version 7.1, PTW Dosimetry, Freiburg, Germany) software was then used to evaluate the QA and completed plans.

The γ index metric was computed using Octavius 4D phantom and VeriSoft software.[17] As a detector, the PTW Octavius 2D Detector 1500 array was used, which has a high resolution (0.1 mGy) with 1405 chambers arranged as a checkboard of size 4.4×4.4×3 mm (0.06 cm^3) in 27×27 cm area. The inclinometer setup allowed the phantom to be synchronized with the rotation speed and angle of the gantry of the linear accelerator as in actual treatment delivery. The direction of the beam always remains perpendicular to the detector array, avoiding any additional correction factor for beam direction. The volumetric γ were evaluated with DD/ DTA values of 3%/3 mm, 3 mm/2%, 2 mm/3% and 2 mm/2% criteria for global and local gamma H&N and pelvis sites.

Analysis of the Gamma Index Using FractionLab, 2D-array and EPID Dosimetry

The comparison of the gamma passing rate of Octavius and EPID was done for 2 mm/3% gamma criteria and with FractionLab for various gamma criteria (0.1%/0.1 mm to 1%/1 mm) in RapidArc Delivery in H&N and pelvis sites.

Statistical Analysis

We conducted a paired t-test on the portal dosimetry and Fraction Lab QA results to determine an appropriate gamma index when using FractionLab-based patient-specific QA, as a 3%/3 mm gamma index was considered when performing QA using portal dosimetry. Statistical analysis was performed using IBM SPSS version 22.0 (IBM Corp., Armonk, NY, USA). The gamma passing rates of portal dosimetry (3%/3mm)

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

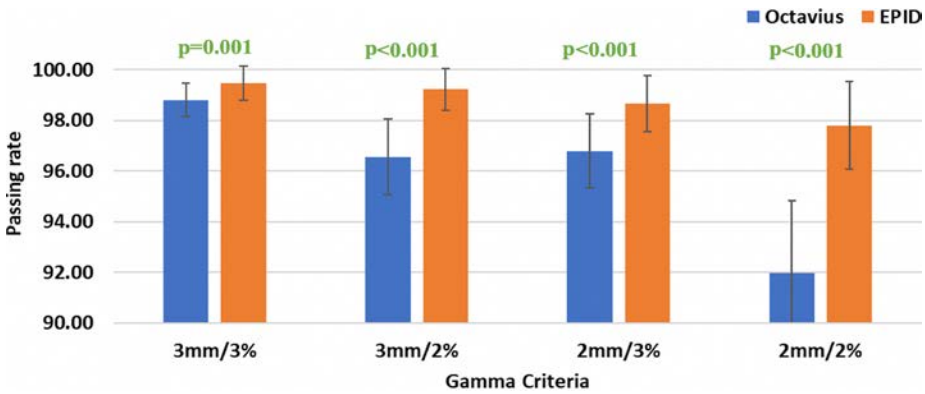

Fig. 1. Variation of gamma passing rate for different global gamma criteria in H&N (Head and Neck).
EPID: Electronic portal imaging device.

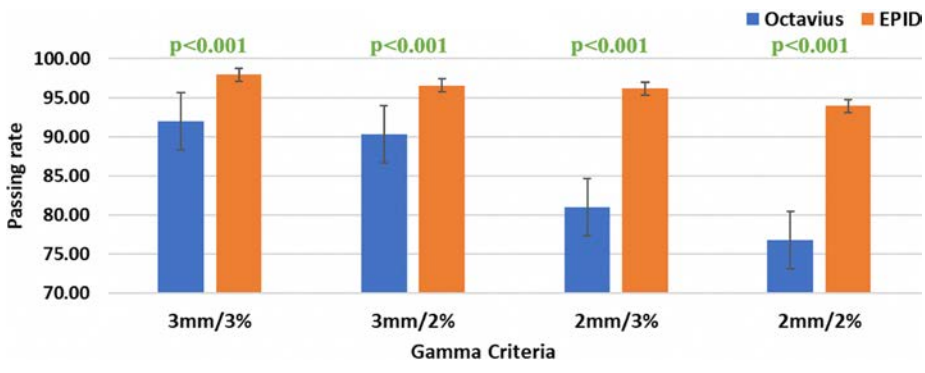

Fig. 2. Variation of gamma passing rate for different local gamma criteria in H&N (Head and Neck).

and FractionLab at various gamma criteria (0.1%/0.1 mm–1%/1 mm) were analyzed, where $p \leq 0.05$ was considered statistically significant.

RESULTS

All plans were analyzed using different gamma criteria: 3 mm/3%, 3 mm/2%, 2 mm/3%, and 2%/2 mm in Octavius and EPID for H&N and pelvis sites, with an analyzed threshold dose of 10%. Figures 1 and 2 illustrate the bar plots of gamma passing results for the EPID and Octavius systems for head and neck sites with global and local gamma criteria. The average Monitor Units (MUs) for H&N plans was 581.89±63.71.

When the global gamma criterion was 2%/2 mm, the average pass rates were 97.79±1.74% for EPID and 91.97±2.85% for Octavius. The average pass rates for the 2 mm/3% criterion were 98.68±1.11% for EPID and 96.79±1.47% for Octavius. For the 3 mm/2% criterion, the average pass rates were 99.22±0.82% for EPID and 96.56±1.50% for Octavius. Finally, the average pass rates for the 3%/3 mm criterion were 99.48±0.67% for EPID and 98.81±0.66% for Octavius.

When using local gamma criteria, the passing rates decreased. The average passing rates for the 2%/2 mm criterion were 93.95±3.48% for EPID and 76.78±5.56% for Octavius. The average pass rates for the 2 mm/3% criterion were 96.22±2.56% for EPID and 81.02±5.17% for Octavius. For the 3 mm/2% criterion, the average pass rates were 96.59±2.34% for EPID and 90.31±3.28% for Octavius. Finally, the average pass rates for the 3%/3 mm criterion were 98.00±1.79% for EPID and 92.01±2.98% for Octavius.

Furthermore, with local gamma criteria, none of the passing rates for the Octavius system met the ≥95% threshold for any gamma criterion. However, the EPID system achieved a passing rate of ≥95% with the 3%/3 mm, 3 mm/2%, and 2 mm/3% gamma criteria.

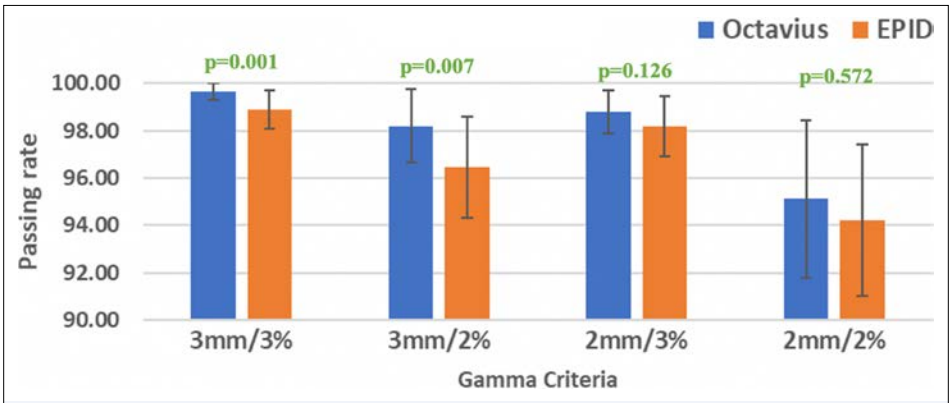

Fig. 3. Variation of gamma passing rate for different global gamma criteria in pelvis.
EPID: Electronic portal imaging device.

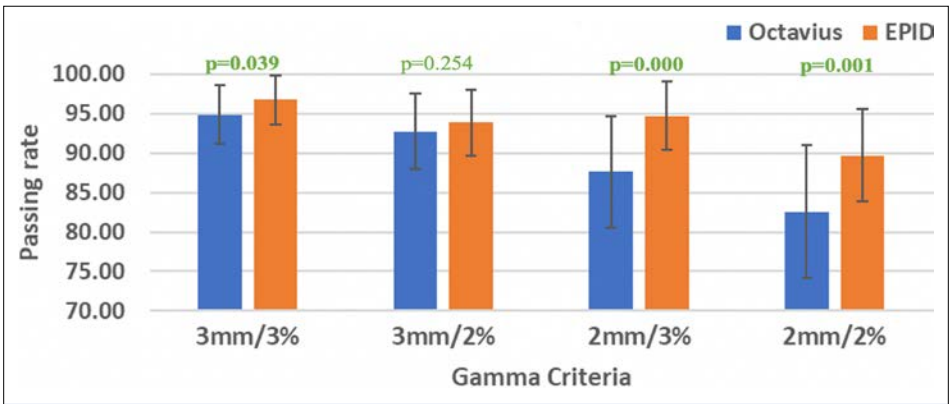

Fig. 4. Variation of gamma passing rate for different local gamma criteria in pelvis.

The comparison between Octavius and EPID showed a statistically significant difference in the gamma criteria for both global and local gamma ($p \leq 0.05$).

Figures 3 and 4 illustrate the bar plots of gamma passing results for the EPID and Octavius systems for pelvis sites with global and local gamma criteria. The average Monitor Units (MUs) for pelvic plans was 543.40±55.48.

When the global gamma criterion was 2%/2 mm, the average pass rates were 94.20±3.20% for EPID and 95.11±2.85% for Octavius. The average pass rates for the 2 mm/3% criterion were 98.18±1.25% for EPID and 98.79±0.994% for Octavius. For the 3 mm/2% criterion, the average pass rates were 96.44±2.13% for EPID and 98.19±1.56% for Octavius. Finally, the average pass rates for the 3%/3 mm criterion were 98.89±0.82% for EPID and 99.65±0.34% for Octavius.

When using local gamma criteria, the passing rates decreased. The average passing rates for the 2%/2 mm criterion were 89.70±5.83% for EPID and 82.57±8.44% for Octavius. The average pass rates for the 2 mm/3% criterion were 94.71±4.31% for EPID and 87.65±7.05% for Octavius. For the 3 mm/2% criterion, the average pass rates were 93.90±4.17% for EPID and 92.74±4.83% for Octavius. Finally, the average pass rates for the 3%/3 mm criterion were 96.76±3.11% for EPID and 94.90±3.76% for Octavius.

A statistically significant difference in gamma pass rate was found for 3 mm/3% (p=0.001) and 3 mm/2% (0.007) global gamma criterion for Octavius and EPID. However, with local gamma criteria except for 3 mm/2% (p=0.254), all criteria showed a significant difference in passing rate.

Tables 1 and 2 show the gamma passing rates for EPID and Octavius under 3%/3mm and 2%/3mm gamma criteria, alongside a comparison with FractionLab at various gamma criteria (0.1%/0.1 mm–1%/1 mm).

For the H&N site, the average gamma passing rate for EPID using the 3%/3 mm global gamma criteria was 99.48% (range: 97.1%–100%). Under the 2 mm/3% criteria, the rate was 98.68% (95.8–99.2%). In the pelvis site, the gamma passing rates for EPID were 98.81% (range: 96.8–99.9%) and 98.17% (range: 95.0–99.90%) for the

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

Table 1 Comparison of gamma passing rates for portal dosimetry and Octavius 2D array with 2 mm/3% gamma criteria, and with FractionLab for various gamma criteria (0.1%/0.1 mm to 1%/1 mm) in RapidArc delivery

Gamma criteria (DD/DTA)	Fraction Lab		EPID				Octavius			
	Gamma passing rates		Gamma criteria (2mm/3%)				Gamma criteria (2mm/3%)			
	Head&Neck	Pelvis	Head&Neck		Pelvis		Head&Neck		Pelvis	
	Mean±SD	Mean±SD	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
0.1/0.1	84.48±1.89	89.10±1.66	98.68±1.11	<0.001	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	<0.001
0.2/0.2	90.51±1.75	93.37±1.20	98.68±1.11	<0.001	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	<0.002
0.3/0.3	94.96±0.76	95.53±1.17	98.68±1.11	<0.001	98.17±1.25	<0.002	96.79±1.47	<0.001	98.79±0.94	<0.003
0.4/0.4	96.59±1.00	96.23±1.62	98.68±1.11	<0.001	98.17±1.25	<0.003	96.79±1.47	**0.201**	98.79±0.94	<0.004
0.5/0.5	98.31±0.46	98.02±1.20	98.68±1.11	**0.120**	98.17±1.25	0.002	96.79±1.47	<0.001	98.79±0.94	**0.242**
0.6/0.6	98.41±0.49	99.01±1.19	98.68±1.11	**0.270**	98.17±1.25	**0.121**	96.79±1.47	<0.001	98.79±0.94	**0.352**
0.7/0.7	98.52±0.50	99.05±0.92	98.68±1.11	**0.504**	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	**0.175**
0.8/0.8	99.38±0.49	99.25±0.78	98.68±1.11	0.005	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	<0.001
0.9/0.9	99.52±0.50	99.53±0.61	98.68±1.11	0.003	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	<0.001
1.0/1.0	99.62±0.49	99.82±0.11	98.68±1.11	<0.001	98.17±1.25	<0.001	96.79±1.47	<0.001	98.79±0.94	<0.001

EPID: Electronic portal imaging device; DD: Dose difference; DTA: Distance to agreement; SD: Standard deviation

3%/3 mm and 2 mm/3% criteria, respectively. These results were compared to those obtained using FractionLab at various gamma criteria (0.1%/0.1 mm–1.0%/1 mm).

EPID (2 mm/3%) and FractionLab also demonstrated statistically significant differences for gamma indices below 0.5%/0.5 mm and above 0.7%/0.7 mm for the H&N site and 0.6%/0.6 mm for the pelvis site. With the 3%/3 mm criteria, only the 0.7%/0.7 mm and 0.8%/0.8 mm indices showed comparable results for the H&N site, while the 0.6%/0.6 mm and 0.7%/0.7 mm indices were comparable for the pelvis site.

In Octavius, for the H&N site, the average gamma passing rate with the 3%/3 mm global gamma criteria was 98.81% (range: 97.0–99.9%), and with the 2 mm/3% criteria, it was 96.79% (range: 92.7–97.0%). For the pelvis site, the rates were 99.65% (range: 98.5–100.0%) and 98.79% (range: 96.4–99.7%), respectively. These results were compared to those obtained using FractionLab at various gamma criteria (0.1%/0.1 mm–1.0%/1 mm).

Furthermore, Octavius (2 mm/3%) and FractionLab exhibited statistically significant differences for all gamma criteria except for 0.4%/0.4 mm for the H&N site and 0.5%/0.5 mm to 0.7%/0.7 mm for the pelvis site. Similarly, with the 3%/3 mm criteria, the 0.5%/0.5 mm and 0.6%/0.6 mm criteria showed comparable results for the H&N site, and the 0.6%/0.6 mm and 0.7%/0.7 mm criteria showed comparable results for the pelvis site.

Figure 5a and b depict the planned fluence image and the fluence image delivered by the log files, respectively, and Figure 5c shows the gamma (0.6%/0.6 mm) evaluation between the planned and delivered fluence images in FractionLab. Furthermore, Figure 6a and b present the gamma evaluation results using EPID and Octavius for the H&N site with a 3%/2 mm global gamma criteria.

DISCUSSION

This study presents a phantom-less method to measure trajectory log files for pretreatment quality assurance (PSQA) and compare the results with those of traditionally used por-

Table 2 Comparison of gamma passing rates for portal dosimetry and octavius 2D array with 3 mm/3% gamma criteria, and with FractionLab for various gamma criteria (0.1%/0.1 mm to 1%/1 mm) in RapidArc delivery

Gamma criteria (DD/DTA)	Fraction Lab		EPID				Octavius			
	Gamma passing rates		Gamma criteria (3%/3mm)				Gamma criteria (3%/3mm)			
	Head&Neck	Pelvis	Head&Neck		Pelvis		Head&Neck		Pelvis	
	Mean±SD	Mean±SD	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
0.1/0.1	84.48±1.89	89.10±1.66	99.48±0.67	<0.001	98.89±0.82	<0.001	98.81±0.66	<0.001	99.65±0.34	<0.001
0.2/0.2	90.51±1.75	93.37±1.20	99.48±0.67	<0.001	98.89±0.82	<0.001	98.81±0.66	<0.001	99.65 ±0.34	<0.001
0.3/0.3	94.96±0.76	95.53±1.17	99.48±0.67	<0.001	98.89±0.82	<0.001	98.81±0.66	<0.001	99.65±0.34	<0.001
0.4/0.4	96.59±1.00	96.23±1.62	99.48±0.67	0.003	98.89±0.82	0.032	98.81±0.66	0.012	99.65±0.34	<0.002
0.5/0.5	98.31±0.46	98.02±1.20	99.48±0.67	0.001	98.89±0.82	0.015	98.81±0.66	**0.135**	99.65±0.34	0.018
0.6/0.6	98.41±0.49	99.01±1.19	99.48±0.67	**0.115**	98.89±0.82	**0.142**	98.81±0.66	**0.111**	99.65±0.34	**0.164**
0.7/0.7	98.52±0.50	99.05±0.92	99.48±0.67	**0.184**	98.89±0.82	**0.175**	98.81±0.66	0.024	99.65±0.34	**0.132**
0.8/0.8	99.38±0.49	99.25±0.78	99.48±0.67	**0.214**	98.89±0.82	0.003	98.81±0.66	0.012	99.65±0.34	0.042
0.9/0.9	99.52±0.50	99.53±0.61	99.48±0.67	<0.001	98.89±0.82	<0.001	98.81±0.66	<0.001	99.65±0.34	<0.001
1.0/1.0	99.62±0.49	99.82±0.11	99.48±0.67	<0.001	98.89±0.82	<0.001	98.81±0.66	<0.001	99.65±0.34	<0.001

EPID: Electronic portal imaging device; DD: Dose difference; DTA: Distance to agreement; SD: Standard deviation

tal dosimetry and detector arrays. We used more complex radiotherapy techniques for two clinical sites, such as the RapidArc planning technique. Since the proposed FractionLab method does not require a phantom or its setup, it minimizes additional workload for clinical physicists. The accuracy reported here is comparable to earlier work by Oh et al.,[13] and we have validated our results using two traditional methods for PSQA.

In a study by Lim et al.,[18] the trajectory logs' results were consistent for static and dynamic delivery and insensitive to MLC calibration errors. Furthermore, AATM task group report 218 recommends a more stringent 3% dose difference (DD) and 2 mm distance-to-agreement (DTA) criteria for dose comparison using gamma analysis with a 10% threshold dose and global normalization, with gamma values of ≥95% as the pass criteria, as opposed to the 3%/3 mm norm proposed in the TG-119 report.[19] However, interpreting the gamma passing rate in a clinical context is challenging; for instance, a pass rate below 95% does not necessarily indicate compromised target coverage or normal organ sparing. Furthermore, in most clinics, the typical response to a failing QA is to conduct multiple re-measurements or to use an alternative. In that context, log file analysis will be used for PSQA.

Therefore, we compared the gamma passing rates for H&N and pelvis sites using different gamma criteria. We found a significant difference in gamma passing rates with 2 mm/3% gamma criteria for the H&N site, and a drastic decrease in gamma passing rates was observed with more stringent local gamma criteria. However, the gamma passing rate was ≥95% with 2 mm/3% global gamma criteria. A comparable gamma passing rate in the pelvis site was observed with ≥95% passing rate using the 2 mm/3% global gamma criteria. The complexity of H&N plans has been reported in previous studies.[20] Interestingly, the decrease in gamma passing rate was more drastic with Octavius than EPID in the H&N site. Therefore, selecting appropriate gamma criteria and QA devices is very important for patient-specific quality assurance (PSQA) for various sites.

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

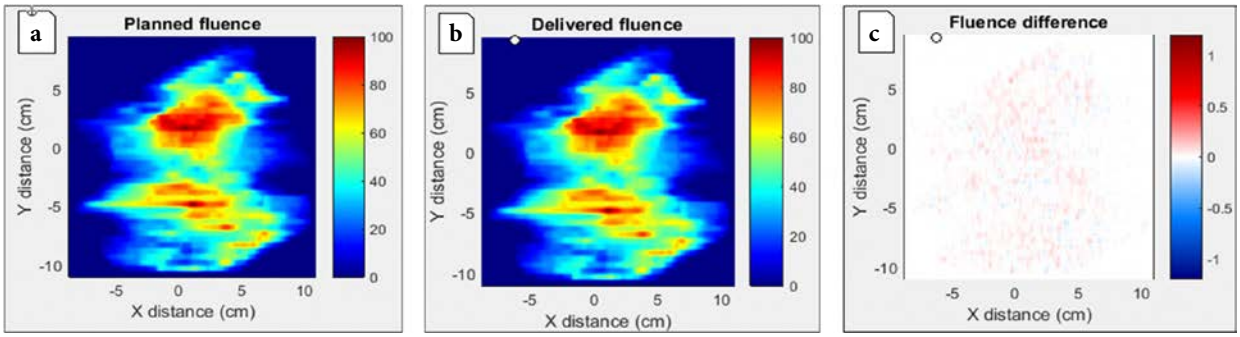

Fig. 5. Patient-specific quality assurance with fractionLab (a) Image of planned fluence, (b) Image of fluence generated by the log-files, and (c) Fluence difference between the planned and delivered fluence images.

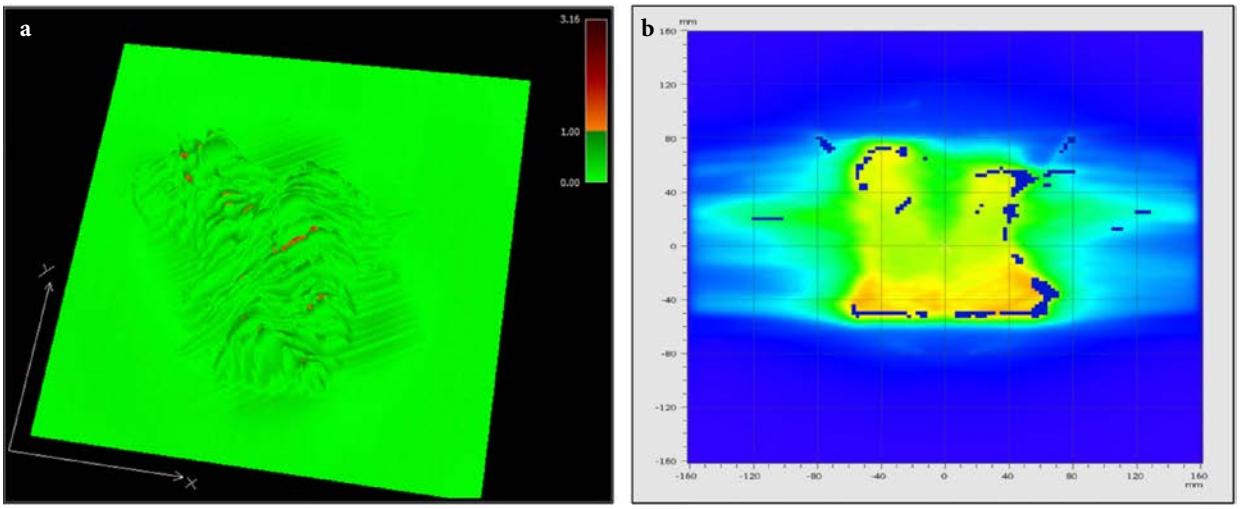

Fig. 6. (a) Three-dimensional gamma (3%/2 mm) image on the portal dose image for H&N site. The height represents the gamma value. (b) Shows the coronal view of gamma evaluation using Octavius with a (3%/2 mm) global criteria for the H&N (Head and Neck) site.

The results showed a significant increase in gamma passing rate with Octavius compared to portal dosimetry in the pelvis site. However, the H&N site showed a different, interesting result, where Octavius passing rates were lower than EPID and decreased drastically with stringent gamma criteria. The same result was found by Urso et al.[21] and Das et al.[22] In a previous study, the average volumetric 3D global gamma indices (for head and neck and pelvic VMAT plans) were reported to be 95.45% and 97.51% using Octavius. Our study is consistent with that reported in the literature, with corresponding values of 96.79% and 98.79%. Though there are differences in planning techniques, it may be mentioned that a plan's modulation complexity score (MCS) weakly correlates with local or global gamma analysis passing rate. MCS is a measure of plan complexity in VMAT.[17,23,24] Furthermore, Jubbier et al.[25] showed that pelvis plans have much simpler complexity consisting of a large aperture, delivering most of the dose with a few smaller compared to H&N, which correlates with our results.

We analyzed the PSQA results using 2 mm/3% and 3%3mm criteria for comparison with trajectory log file results, which were analyzed in FractionLab with various gamma indices for H&N and pelvis sites. The results showed that performing gamma index analysis in the range of 0.4%/0.4 mm to 0.7%/0.7 mm is appropriate when using FractionLab for patient-specific QA in RA. This implies the clinical performance of FractionLab by comparing its QA results using EPID and Octavius for various gamma indices with the results of patient-specific QA in RA treatment. The

proposed method can present the appropriate gamma index when performing patient-specific QA with FractionLab. Recent studies have corroborated these findings, suggesting that lower gamma index thresholds provide a more stringent and potentially more accurate assessment of treatment delivery accuracy. [26,27] By comparing FractionLab's QA results with those obtained from established methods like EPID and Octavius, our study highlights the robustness and clinical relevance of FractionLab in ensuring precise RA treatment delivery.

Therefore, PSQA practices can be significantly improved by log-file-based evaluation. The small sample size in our current study could be a limitation regarding the generalizability of our findings. Additionally, variations in accelerators and equipment used across different institutions could impact the universal relevance of our results. We recommend a comprehensive study across various institutions, including the equipment and methodological differences, to improve the wider applicability of future findings.

CONCLUSION

The present study demonstrates that the phantom-less method using FractionLab for pretreatment quality assurance (PSQA) is a viable alternative to traditional methods, offering comparable accuracy while reducing the workload for clinical physicists. By validating against EPID and Octavius, we established that appropriate gamma criteria selection is crucial for different clinical sites. FractionLab shows consistent and reliable QA results for complex radiotherapy techniques like RapidArc, making it a practical tool for enhancing PSQA efficiency and effectiveness.

Conflict of Interest: All authors declared no conflict of interest.

Financial Support: None declared.

Use of AI for Writing Assistance: No AI technologies utilized.

Authorship Contributions: Concept – S.M., B.K.S., K.J.M.D.; Design – S.M., B.K.S., K.J.M.D.; Supervision – B.K.S., K.J.M.D.; Data collection and/or processing – S.M., B.K.S., K.J.M.D.; Data analysis and/or interpretation – S.M., B.K.S., K.J.M.D.; Literature search – S.M., B.K.S., K.J.M.D.; Writing – S.M., B.K.S., K.J.M.D.; Critical review – K.J.M.D., B.K.S., S.M.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Mechalakos JG, Dieterich S, Fong de los Santos LE, Fontenla SC, Hanley J, Harwalkar VA, et al. Electronic charting of radiation therapy planning and treatment: Report of Task Group 262. Med Phys 2021;48(11):e927–68.
2. Miften M, Olch A, Mihailidis D, Moran J, Pawlicki T, Molineu A, et al. Tolerance limits and methodologies for IMRT measurement-based verification QA: Recommendations of AAPM Task Group No. 218. Med Phys 2018;45(4):e53–83.
3. Chan GH, Chin LCL, Abdellatif A, Bissonnette JP, Buckley L, Comsa D, et al. Survey of patient-specific quality assurance practice for IMRT and VMAT. J Appl Clin Med Phys 2021;22(7):155–64.
4. El Hajami A, Dadouch A, Tajmouati J, Maghnouj A, Youssoufi MA, Baraka M El, et al. Evaluation of the performance of an ionization chamber cylindrical (PTW) by the ELEKTA linear accelerator: Case of pulsed radiation. J Phys Conf Ser 2019;1292(1):012006.
5. Low DA, Moran JM, Dempsey JF, Dong L, Oldham M. Dosimetry tools and techniques for IMRT. Med Phys 2011;38(3):1313–38.
6. Cruz W, Narayanasamy G, Regan M, Mavroidis P, Papanikolaou N, Ha CS, et al. Patient specific IMRT quality assurance with film, ionization chamber and detector arrays: Our institutional experience. Radiat Phys Chem 2015;115:12–6.
7. Dogan N, Mijnheer BJ, Padgett K, Nalichowski A, Wu C, Nyflot MJ, et al. AAPM Task Group Report 307: Use of EPIDs for patient-specific IMRT and VMAT QA. Med Phys 2023;50(8):e865–903.
8. Chan LT, Tan YI, Tan PW, Leong YF, Khor JS, Teh MW, et al. Comparing log file to measurement-based patient- specific quality assurance. Phys Eng Sci Med 2023;46(1):303–11.
9. Zhao X, Stanley DN, Cardenas CE, Harms J, Popple RA. Do we need patient-specific QA for adaptively generated plans? Retrospective evaluation of delivered online adaptive treatment plans on Varian Ethos. J Appl Clin Med Phys 2023;24(2):1–8.
10. Chen L, Luo H, Li S, Tan X, Feng B, Yang X, et al. Pretreatment patient-specific quality assurance prediction based on 1D complexity metrics and 3D planning dose: Classification, gamma passing rates, and DVH metrics. Radiat Oncol 2023;18(1):192.
11. Lau ML, Abdullah R, Jayamani J. Electronic portal imaging device in pre-treatment patient-specific quality assurance of volumetric-modulated arc therapy delivery. J Radiother Pract 2023;22:e63.
12. Glide-Hurst CK, Lee P, Yock AD, Olsen JR, Cao M, Siddiqui F, et al. Adaptive Radiation Therapy (ART) strategies and technical considerations: A state of the

Turk J Oncol 2025;40(2):141–150
doi: 10.5505/tjo.2024.4447

ART review from NRG oncology. Int J Radiat Oncol Biol Phys 2022;109(4):1054–75.
13. Oh SA, Kim SY, Park J, Park JW, Yea JW. Clinical performance of FractionLab in patient-specific quality assurance for intensity-modulated radiotherapy: A retrospective study. J Yeungnam Med Sci 2022;39(2):108–15.
14. Wojtasik AM, Bolt M, Clark CH, Nisbet A, Chen T. Multivariate log file analysis for multi-leaf collimator failure prediction in radiotherapy delivery. Phys Imaging Radiat Oncol 2020;15:72–6.
15. Chuang KC, Giles W, Adamson J. A tool for patient-specific prediction of delivery discrepancies in machine parameters using trajectory log files. Med Phys 2021;48(3):978–90.
16. Agarwal A, Rastogi N, Maria Das K, Yoganathan S, Udayakumar D, Kumar S. Investigating the electronic portal imaging device for small radiation field measurements. J Med Phys 2017;42(2):59–64.
17. Xue X, Luan S, Ding Y, Li X, Li D, Wang J, et al. Treatment plan complexity quantification for predicting gamma passing rates in patient-specific quality assurance for stereotactic volumetric modulated arc therapy. J Appl Clin Med Phys 2024;25(9):e14432.
18. Lim SB, Godoy Scripes P, Napolitano M, Subashi E, Tyagi N, Cervino Arriba L, et al. An investigation of using log-file analysis for automated patient-specific quality assurance in MRgRT. J Appl Clin Med Phys 2021;22(9):183–8.
19. Ezzell GA, Burmeister JW, Dogan N, Losasso TJ, Mechalakos JG, Mihailidis D, et al. IMRT commissioning: Multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med Phys 2009;36(11):5359–73.
20. Deng J, Liu SY, Huang Y, Li X, Wu X. Evaluating AAPM-TG-218 recommendations: Gamma index tolerance and action limits in IMRT and VMAT quality assurance using SunCHECK. J Appl Clin Med Phys 2024;25(6):1–12.
21. Urso P, Lorusso R, Marzoli L, Corletto D, Imperiale P, Pepe A, et al. Practical application of Octavius®-4D: Characteristics and criticalities for IMRT and VMAT verification. J Appl Clin Med Phys 2018;19(5):517–24.
22. Das S, Kharade V, Pandey V, KV A, Pasricha RK, Gupta M. Gamma index analysis as a patient-specific quality assurance tool for high-precision radiotherapy: A clinical perspective of single institute experience. Cureus 2022;14(10):e30885.
23. Rajasekaran D, Jeevanandam P, Sukumar P, Ranganathan A, Johnjothi S, Nagarajan V. A study on the correlation between plan complexity and gamma index analysis in patient specific quality assurance of volumetric modulated arc therapy. Reports Pract Oncol Radiother 2015;20(1):57–65.
24. Noblet C, Duthy M, Coste F, Saliou M, Samain B, Drouet F, et al. Implementation of volumetric-modulated arc therapy for locally advanced breast cancer patients: Dosimetric comparison with deliverability consideration of planning techniques and predictions of patient-specific QA results via supervised machine learning. Phys Medica 2022;96:18–31.
25. Jubbier ON, Abdullah SS, Alabedi HH, Alazawy NM, Al-Musawi MJ. The effect of Modulation Complexity Score (MCS) on the IMRT treatment planning delivery accuracy. J Phys Conf Ser 2021;1829(1):012017.
26. Cilla S, Viola P, Romano C, Craus M, Buwenge M, Macchia G, et al. Prediction and classification of VMAT dosimetric accuracy using plan complexity and log-files analysis. Phys Medica 2022;103:76–88.
27. Silvestri V, Raspanti D, Guerrisi MG, Falco MD. Clinical implementation of a log file-based machine and patient QA system for IMRT and VMAT treatment plans. Phys Medica 2023;108:102570.