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Comparison of Patient-Specific Quality Assurance Devices in Radiation Therapy

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Abstract

This study aimed to compare the results of patient-specific quality assurance (PSQA) between MapCHECK and Octavius for radiation therapy. A total of 50 patients with passing PSQA results were included. The point dose difference (DD) and gamma passing rate (GPR) were analyzed to evaluate the agreement between the measured and planned data, and the PSQA results from the two quality assurance (QA) devices were compared for all cases. The DDs and GPRs were within the tolerance ranges in all of the cases. The average GPR difference between the two detectors was statistically significant for the brain and the H&N values for the gamma criteria were 3%/3 mm, 2%/2 mm, and 1%/1 mm. These PSQA systems can be used interchangeably for routine PSQA during the delivery of radiation therapy.

Keywords: *Patient-Specific Quality Assurance, MapCHECK, Octavius, Plan Complexity, Radiation Therapy*

INTRODUCTION

Advanced radiation therapy (RT) techniques such as intensity-modulated RT (IMRT), volumetric modulated arc therapy (VMAT), and stereotactic body RT (SBRT) are widely used to obtain highly accurate radiation dose distributions to targets while minimizing doses to surrounding normal tissues (Miften, 2018; Sherouse, 2002; Cho, 2018). Pretreatment patient-specific delivery quality assurance (PSQA) is important to improving the accuracy and treatment outcomes of RT. Therefore, various two-dimensional (2D) detectors have been used to verify accurate dose delivery to patients, as well as ease-of-use, many of which provide real-time readouts of QA results (Li, 2009; Lee, 2021).

The most common PSQA method is verification by comparing the dose distribution and point dose differences calculated using a treatment planning system (TPS) vs those that are measured using a dosimetric QA device such as ion-chambers or 2-dimensional [2D] arrays (Chang, 2023). To perform PSQA in IMRT, various 2D PSQA devices such as MapCHECK (Sun Nuclear Corporation, Melbourne, FL, USA), IMRT MatriXX (IBA Dosimetry, Schwarzenbruck, Germany), and PTW 729 array (PTW Freiburg GmbH, Germany) have been developed and used (Jursinic, 2010; Keeling, 2013). Three-dimensional (3D) PSQA can also be performed using the ArcCEHCK (Sun Nuclear Corporation, Melbourne, FL, USA) and Delta4 (ScandiDos, Uppsala, Sweden) systems (Spezi, 2005; Aristophanous, 2016; Chang, 2020). A dosimetric check (DC) system (LAP Laser, FL, USA) is often used to perform in vivo dosimetry for helical tomotherapy (HT) (Deshpandes, 2017). Advanced PSQA systems such as the integrated quality monitor (IQM; iRT Systems GmbH, Germany), are currently being used for portal dosimetry, along with an electronic portal imaging device (EPID), for IMRT (Razinskas, 2018). Recently, several studies have investigated and compared the PSQA results output by various devices (Son, 2015; Markovic, 2019).

This study aimed to comprehensively compare and analyze the PSQA results of the MapCHECK and Octavius (PTW Freiburg GmbH) 2D array systems for various anatomic sites.

METHODOLOGY

Patient Characteristics

Fifty patients with passing PSQA measurements were randomly selected for this analysis of their PSQA results. Brain, head and neck (H&N), rectal, breast, and prostate cancer cases were included, with 10 patients for each

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region. All of the included patients were treated using a linear accelerator.

MapCHECK and Octavius detectors

Table 1 compares the specifications of the MapCHECK (Model 1175; Sun Nuclear Corporation) and Octavius (1000 SRS; PTW Freiburg GmbH) PSQA devices. These two devices were described in detail in a previously published study (Chang, 2013). MapCHECK comprises 445 N-type diode detectors over an area of 22 × 22 cm2. It consists of an area of 10 × 10 cm2 with a detector spacing of 7.07 mm, as well as an external perimeter array with a detector spacing of 14.14 mm (Chang, 2011). The active area of each detector is 0.8 × 0.8 cm2. This device can measure doses of up to 330 cGy (Jursinic, 2010). The Octavius is a liquid-filled ionization chamber with 977 detectors. Its maximum field sizeis 11 × 11 cm2 , and its chamber size is 2.5 × 2.5 × 0.5 mm3. The spacings in the central (5.5 × 5.5 cm2) and outer regions (11 × 11 cm2) are 2.5 mm and 5 mm, respectively (Son, 2015).

Table 1. Comparison of MapCHECK and Octavius PSQA device specifications.

Features	MapCHECK	OCTAVIUS
Model No.	1175	1000 SRS
Detector type	N-type diode detectors	Liquid-filled ionization chamber
Number of detectors	445	977
Array size	22 × 22 cm^2	11 cm × 11 cm^2
Detector spacing	Center area: 7.07 mm Outer area: 14.14 mm	Center area: 2.50 mm Outer area: 5.00 mm
Active detector area	0.8 × 0.8 cm^2	2.5 × 2.5 × 0.5 mm^3 (0.003 cm^3)

PSQA Process and Analysis

All PSQA plans were generated using a TPS. The source-detector distance was set to 100 cm, and all PSQAs were delivered to the two detectors. Planned data were transferred to SNC patients and VeriSoft software. Measured real-world data were compared with the results of the two detectors to analyze the point dose difference (DD) and gamma pass rate (GPR). The analysis threshold was set at 10% of the global maximum. Point dose differences were within the acceptable range of ±5% for all measurements. GPRs based on 3%/3 mm, 2%/2 mm, and 1%/1 mm were analyzed for all measurements (Son, 2015). In this study, the DD and GPR results were analyzed using root mean square errors (RMSEs) for all cases, with smaller RMSE values indicating better device performance in terms of PSQA.

RESULTS

Dose Difference

The DDs measured using the MapCHECK and Octavius detectors for the various treatment sites are shown in Fig. 1. On average, the DDs were within ±1.6% for all of the cases (Fig. 1). For RMSE, the DDs were within 7.3 for the two devices in all cases (Table 2). The breast case showed the maximum RMSE (7.24) when the DQA was performed with the MapCHECK detector. The H&N case provided the minimum RMSE (0.03) with the OCTAVIUS device. The RMSE value provides information regarding the performance of the device by evaluating the comparison of the difference between the planned and measured dose.

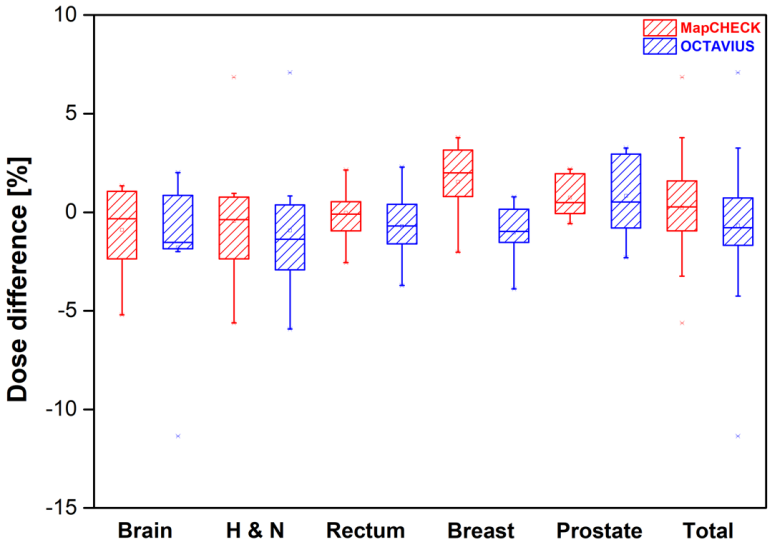


Figure 1. Box plots of the dose differences obtained using the MapCHECK (red) and Octavius (blue) devices, for all of the cases.

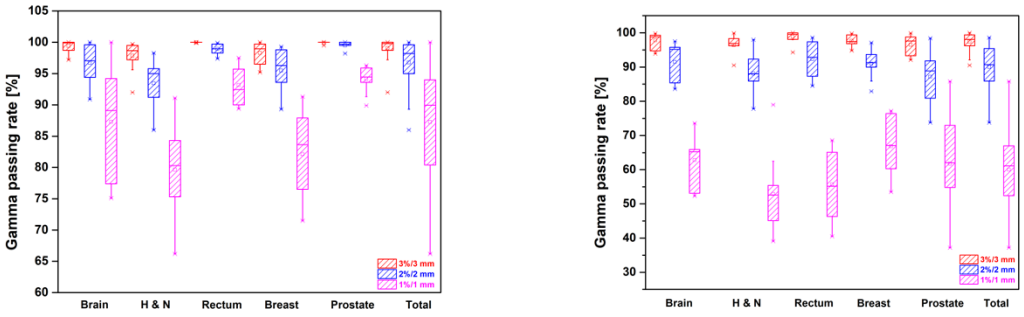
Table 2. Comparison of point-dose differences using the RMSEs of the two PSQA devices, for all of the cases

	MapCHECK	Octavius
Brain	0.29	0.91
H&N	2.36	0.03
Rectum	3.94	0.04
Breast	7.24	0.05
Prostate	3.54	0.94
Total	2.23	2.80

PSQA: patient-specific quality assurance, H&N: head and neck.

GPR

Fig. 2 show the GPR results between the MapCHECK and Octavius devices, according to the 3%3 mm, 2%/2 mm, and 1%/1 mm criteria, for all of the cases. The average MapCHECK GPRs were higher than the Octavius ones for all of the cases. The difference between the two detectors increased when the GPR criteria were adjusted to 2%/2 mm and 1%/1 m.



(a) (b)

Figure 2. Box plots of GPRs using gamma criteria of 3%/3 mm, 2%/2 mm, and 1%/1 mm for the MapCHECK (A) and Octavius (B) devices.

The MapCHECK RMSEs were within 1.6, 3.6, and 8.4 for gamma criteria of 3%3 mm, 2%/2 mm, and 1%/1 mm criteria, respectively. The Octavius RMSEs were within 2.5, 6.0, and 11.4 for gamma criteria of 3%3 mm, 2%/2 mm, and 1%/1 mm criteria, respectively. The lowest RMSEs were obtained using MapCHECK, and the RMSEs values for gamma criteria of 3%3 mm, 2%/2 mm, and 1%/1 mm were 0.04, 0.66, and 2.00, respectively. The highest RMSE (13.64) for Octavius was in a prostate case. The RMSEs of MapCHECK were lower than those of Octavius for all of the cases (Table 3).

Table 3. Comparison of GPRs using the RMSEs for the two PSQA devices for all of the analyzed cases

	Gamma criteria	**MapCHECK**	**Octavius**
Brain	3%/3 mm	0.90	2.23
	2%/2 mm	3.05	5.47
	1%/1 mm	8.38	6.99
H&N	3%/3 mm	2.29	2.65
	2%/2 mm	3.96	5.64
	1%/1 mm	7.34	11.01
Rectum	3%/3 mm	0.04	1.78
	2%/2 mm	0.86	5.58
	1%/1 mm	2.93	9.43
Breast	3%/3 mm	1.68	1.68
	2%/2 mm	3.74	3.93
	1%/1 mm	6.63	8.31
Prostate	3%/3 mm	0.19	2.71
	2%/2 mm	0.66	6.63
	1%/1 mm	2.00	13.64
Total	3%/3 mm	1.58	2.44
	2%/2 mm	3.53	6.00
	1%/1 mm	8.33	11.33

GPR: gamma passing rate, RMSE: root mean square error, PSQA: patient-specific quality assurance, H&N: head and neck.

DISCUSSION

This study compared the dosimetric results of two commercially available PSQA devices (MapCHECK and Octavius) for various clinical cases. The DDs and GPRs were within the tolerance ranges for all of the cases. The average GPRs of MapCHECK were higher than those of Octavius across all of the cases.

In all of the cases, the average DDs between the two detectors were similar, except for the breast cases (Fig. 1). In the breast cases, a significant difference was observed between the two devices (Table 2). This result is attributable to the lack of DQA cases and the setup uncertainty of the devices. Therefore, we plan to conduct a study to determine the reason for the difference between the two devices by analyzing a larger number of breast cases. The RMSEs of the point-dose differences for Octavius were lower than those for MapCHECK in each case. These results show that the Octavius detector is more accurate than MapCHECK for point-dose measurements (Fig. 1). Although the DDs were within the tolerance level, not all measured points passed, and the DDs did not pass at some of the measurement points. However, at our institution, the average DD was found to be within the acceptable range.

We confirmed that the GPRs of MapCHECK were higher vs those of Octavius for gamma criteria of 3%/3 mm, 2%/2 mm, and 1%/1 mm, for all of our cases (Fig. 2). The MapCHECK results were confirmed to be consistent with those of a previously published study on linear-accelerator-based IMRT. Chang et al. showed that the GPRs using MapCHECK were > 99.0% in all of their cases. They confirmed that the overall average GPRs for the 3%/3 mm criteria were 97.4% for both of the devices, in various clinical cases (Chang, 2023). Son et al. demonstrated that the average GPR was 99.04% for gamma criteria of 3%/3 mm. They reported that the MapCHECK system showed good agreement with Matrixx (Son, 2014). Although DQA was performed for HT, they showed that the GPRs with MapCHECK were > 96% for the brain, H&N, and rectal cases (Chang, 2020). We confirmed that the GPRs of Octavius ranged between 96–98% for all of the cases, using the 3%/3 mm criteria. We confirmed that the Octavius GPRs were between 87–92% for all cases, using 2%/2 mm criteria. Markovic et al. showed that Octavius GPRs were > 90% for gamma criteria of 2%/2 mm. These results are consistent with those of a previous study (Markovic, 2019). The RMSEs of the GPRs for Octavius were higher than those for MapCHECK for all three criteria. Although the clinical cases included in this study were not identical, these results were consistent with those of previous studies (Chang, 2023; Chang, 2020). When compared to the RMSE obtained using MapCHECK for HT, it was confirmed that the RMSE value in this study was ~2× as low (Chang, 2020). In HT, the thread effect caused by the helical field junction is increased; therefore, an increased number of MUs results in increased radiation leakage. Therefore, the GPR results were lower (L´arraga-Guti´errez, 2014; Chen, 2011).

This study was subject to several key limitations inherent to retrospective studies. The number of patients in this study (n = 50) was relatively small. We plan to collect and analyze a large quantity of patient data to identify variables that have specific correlations with the PSQA results for each clinical case. However, this merits further investigation in a future study.

CONCLUSION

In this study, we compared the dosimetric results of two PSQA devices for RT. The DDs were within the tolerance range of ±5% for all of the cases. Based on the findings of this study, the RMSEs of DD were within 2.80 for the two detectors in all of our cases. The average GPRs of MapCHECK were higher than those of Octavius in all of the cases. Based on these findings, we confirmed that these two detector systems can be used interchangeably for routine PSQA.

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