

FF and FFF patient specific QA using new Varian aS1200 portal imager and compare with PTW Octavius 1500

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Abstract

Background: An electronic portal imaging device (EPID) is an effective tool for patient specific quality assurance (QA) because of its performance and user-friendly. However, signal saturation can occur when using imager in high dose rate range, especially in flattening filter free (FFF) beams.

Objective: To investigate a new Varian EPID (aS1200) with Portal Dosimetry implementation for patient specific QA in FF and FFF beams with a new gamma index criteria, which proposed by AAPM TG-218, and compared the result with PTW Octavius 1500 with PTW Octavius 4D system.

Materials and methods: Randomly selected thirty patient's VMAT plans were recalculated into sixty plans by the other beam mode using Eclipse TPS (V.13.6). Therefore, sixty plans were composed of thirty FF plans and thirty FFF plans in various tumor sites and applied for patient specific QA implementation by aS1200 EPID and PTW Octavius 1500. Gamma index criteria from AAPM TG-119 (global normalization with 3% DD/3 mm DTA and 10% low dose threshold) and AAPM TG-218 (global normalization with 3% DD/2 mm DTA and 10% low dose threshold) were applied for result interpretation.

Results: In FF and FFF plans, the results showed most of the percent gamma passing rate of aS1200 EPID were slightly lower with higher SD than PTW Octavius 1500, except in stringent criteria for FFF plans. According to the AAPM TG-119, the mean gamma passing rate of aS1200 EPID and PTW Octavius 1500 was $99.02\% \pm 1.60\%$ and $99.80\% \pm 0.52\%$, respectively. For AAPM TG-218, the results of aS1200 EPID and PTW Octavius 1500 was $98.36\% \pm 2.50\%$ and $98.66\% \pm 1.86\%$, respectively.

Conclusion: The results of the study revealed that both systems showed comparable results for a new gamma criteria. Both systems can be used as alternative detectors for patient specific QA.

Keywords: aS1200 EPID, Patient specific QA, PTW Octavius 1500

บทคัดย่อ

หลักการและเหตุผล: ปัจจุบันอุปกรณ์รับภาพอิเล็กทรอนิกส์ (EPID) มีความสำคัญในการทำประกันคุณภาพแผนการรักษาเนื่องจากใช้งานง่ายและมีคุณสมบัติที่เหมาะสม อย่างไรก็ตามการใช้ EPID อาจเกิดภาวะอ้อมตัวได้เมื่อใช้ในการวัดรังสีที่ให้อัตราปริมาณรังสีต่อหน่วยเวลาสูง โดยเฉพาะอย่างยิ่งในลำรังสีชนิดที่ไม่มีตัวกรอง

วัตถุประสงค์: ศึกษาการใช้งานอุปกรณ์รับภาพอิเล็กทรอนิกส์รุ่นใหม่ aS1200 ในการใช้ประกันคุณภาพแผนการรักษาทั้งแบบมีตัวกรองรังสีและไม่มีตัวกรองรังสี และประเมินผลโดยใช้วิธี gamma evaluation ซึ่งถูกเสนอโดย AAPM TG-218 โดยเปรียบเทียบผลการทดลองกับหัววัดรังสีระนาบแบบแตกประจุ PTW Octavius 1500

วัสดุและวิธีการ: เลือกแผนการรักษาแบบสุ่มจำนวน 30 แผน และนำมาคำนวณใหม่โดยใช้รังสีอีกรูปแบบหนึ่ง ดังนั้นแผนการรักษาทั้งหมด 60 แผน แบ่งเป็นแผนการรักษาแบบมีตัวกรองรังสี 30 แผน และไม่มีตัวกรองรังสี 30 แผน จะถูกใช้ในการประกันคุณภาพแผนการรักษาโดยใช้ aS1200 EPID และ PTW Octavius 1500 และประเมินผลโดยใช้เกณฑ์ gamma evaluation จาก AAPM TG-119 และ 218

ผลการศึกษา: aS1200 EPID ได้ค่า $\gamma\%$ เทียบเท่ากับ PTW Octavius 1500 ทั้งในแผนการรักษาที่ใช้ตัวกรองรังสีและไม่ใช้ตัวกรองรังสี โดยสำหรับ AAPM TG-119 ค่าเฉลี่ย $\gamma\%$ ของ aS1200 EPID และ PTW Octavius 1500 คือ $99.02\% \pm 1.60\%$ และ $99.80\% \pm 0.52\%$ ตามลำดับ และสำหรับ AAPM TG-218 ค่าเฉลี่ย $\gamma\%$ ของ aS1200 EPID และ PTW Octavius 1500 คือ $98.36\% \pm 2.50\%$ และ $98.66\% \pm 1.86\%$ ตามลำดับ

ข้อสรุป: จากผลการศึกษาพบว่าอุปกรณ์วัดรังสีทั้ง 2 ชนิดได้ผลการศึกษาที่ใกล้เคียงกันในเกณฑ์การประเมินผลของ AAPM TG-218 ดังนั้นอุปกรณ์วัดรังสีทั้ง 2 ชนิด สามารถใช้ในการประกันคุณภาพแผนการรักษาได้

คำสำคัญ: การประกันแผนการรักษา, อุปกรณ์รับภาพแนวระนาบแบบแตกประจุ รุ่น PTW Octavius 1500, อุปกรณ์รับภาพอิเล็กทรอนิกส์รุ่น aS1200

Introduction

Electronic Portal Imaging Devices (EPIDs) have been used for patients' positioning verification. By reason of the excellent dose linearity response, large detection area, high spatial resolution, digital data acquisition, and convenience to use of the EPID, so EPIDs are an attractive tool for patient specific quality assurance (QA)^[1]. Nonetheless, EPIDs have a limited condition for dose measurement such as energy dependence^[2], ghosting artifact^[3], backscattering from supporting arm^[4] and especially the detector saturation while using flattening filter free (FFF) beams^[5].

At Siriraj Hospital, we have used an aS1000 EPID for a patient specific QA in flattening filter (FF) plans and PTW Octavius 1500 with PTW Octavius 4D phantom for FFF plans. At present, an aS1200 EPID with a new version of Portal Dosimetry has been developed for overcoming the pitfalls, which occur in aS1000 EPID, such as improvement of spatial resolution, additional backscatter shielding plate and better charge readout performance. Therefore, aS1200 EPID is an attractive tool for a patient specific QA, especially in FFF beams.

Furthermore, we have used gamma analysis with global normalization of 3% DD/3mm criterion which proposed

by AAPM TG-119^[6] for analyzing the QA results. Nowadays, AAPM TG-218^[7] suggests a new gamma index criterion which is global normalization of 3% DD/2mm DTA with 10% dose threshold for using in conventional technique QA. However, this can cause a questionable for using criteria for gamma analysis.

The goal of present study is to investigate the feasibility of aS1200 EPID implementation for a patient specific QA and also a new gamma criterion proposed by AAPM TG-218. The results of the test were compared against PTW Octavius 1500.

Materials and Methods

Patient's VMAT plan preparation

Randomly selected 30 clinical patient's VMAT plans of different sites were duplicated and recalculated to the other beam mode. For example, the original plan using 6 MV FF beams, was duplicated and recalculated using 6 MV FFF beams. Therefore, the treatment plans were composed of 60 plans of 18 brain tumor, 4 head & neck cancer, 4 lung cancer, 16 GI cancer, 4 GU cancer, and 14 prostate cancer plans. All the treatment plans were from Division of Radiation Oncology, Department of Radiology, Faculty of Medicine Siriraj Hospital.

The VMAT plans (with a total of 165 arcs) were generated with Eclipse treatment planning system version 13.6 (Varian Medical System, Palo Alto, CA). The analytical anisotropic algorithm (AAA) and Acuros XB were used for calculation of dose according to the plans, which generated by 6 and 10 MV for flattening filter (FF) and flattening filter free (FFF) beams. The maximum dose rate of 6 and 10 MV plans was 600 MU/min. For 6 FFF and 10 FFF, the maximum dose rate used in the plans were 1400 and 2400 MU/min, respectively. The grid size was set at 2.5 mm.

Pre-treatment patient specific quality assurance

A TrueBeam linear accelerator with Millennium™ 120 multileaf collimator (MLC) (Varian Medical System, Palo Alto, CA) was used for performing all measurements using 6 and 10 MV with FF and FFF beams. The latest version of Varian electronic portal imaging device (aS1200 EPID) with Portal Dosimetry software version 13.6 (Varian Medical System, Palo Alto, CA) and PTW Octavius 1500 with 4D phantom (PTW, Freiberg, Germany) were used in our study.

The aS1200 EPID, which is mounted on TrueBeam LINAC, has a maximum resolution of 1280×1280 over maximum imager area of 43×43 cm², so the spatial pixel resolution of aS1200 EPID is 0.336 mm. The maximum frame rate is 25 frames per second, which is about five times higher than the previous version (aS1000 EPID). An additional absorber plate, which locates between the detection layers and supporting arm, is added for blocking the backscatter from the supporting arm. The standard calibration and configuration of the imager, described by Van Esch et al. ^[8], were performed before the imager utilization. The EPID was set to 100 cm SDD, as shown in **figure 1A**. The Integral image was used for acquiring the measured portal dose image (PDI). The measured PDI was sent to Portal Dosimetry software for the result evaluation.



A PTW Octavius 1500 with PTW 4D phantom, which is used as a routine detector for the QA of FFF beams at Siriraj Hospital, were utilized for comparing the results from aS1200 EPID. A spatial resolution of the detector has 5 mm center-to-center distance in each row and 7.5 mm for diagonal direction. The maximum detection area of the detector is 27×27 cm². PTW Octavius 1500 consists of 1405 vented ionization chamber and the area for each chamber is 4.4×4.4 mm². Therefore, the volume in each chamber is 0.058 cm³. In the study, the detector was placed in the 4D phantom and set to 100 cm SAD, as shown in **figure 1B**. A wireless inclinometer was used for the gantry rotation tracking, which makes the detector always located perpendicular to the gantry. In the study, PTW Octavius 1500 was used as a reference detector due



Figure 1. Machine set up. (A) aS1200 EPID and (B) PTW Octavius 1500 with 4D phantom.

to the performance of the detector, as proposed by Stellijes et al.^[9]. Before using the detector, calibration of the signal for each energy must be performed.

The VMAT plans were recalculated for plan verification, which used for both detectors. The portal dose image prediction (PDIP) algorithm, which is a dose calculation algorithm in Portal Dosimetry, was used for calculation of predicted PDI.

Evaluation of patient's VMAT plans QA

To evaluate the results, the gamma evaluation method proposed by Low et al.^[10], was used in the study. The gamma evaluation method is composed of dose difference (DD) and distance-to-agreement (DTA) in a single measurement. This evaluation method utilizes the mathematics equation for analyzing the discrepancy between predicted dose image in TPS and measured dose image.

Sixty patient's VMAT plans were divided into two categories, which are thirty FF plans (with a total of eighty three arcs) and thirty FFF (with a total of eighty two arcs) plans. A gamma index was set at 3% DD/3mm DTA with global normalization, which has used for a patient specific QA at Siriraj Hospital, and 3% DD/2 mm with global normalization,

which proposed by AAPM TG-218, with 10% dose threshold for evaluation in every arc. The percent gamma passing rate (γ) and mean γ with standard deviation (SD) were used for evaluation of the QA results. Furthermore, a traditional gamma index criteria (3% DD/3mm DTA a global normalization with 10% dose threshold) and AAPM TG-218 criteria (3% DD/2mm DTA a global normalization with 10% dose threshold) were analyzed for all sixty patient's VMAT plans. The plan was analyzed arc-by-arc based on the traditional gamma criteria and compared the results with the new gamma criteria. Wilcoxon Signed-Rank with $\alpha = 0.05$ was used for statistical analysis in this study.

Results

Patient specific QA in flattening filter and flattening filter free beams

Table 1 shows the percent gamma passing rate of a pre-treatment patient specific QA of aS1200 EPID measurements and compared against PTW Octavius 1500. The verification plans were planned using FF and FFF beam techniques. The traditional criteria gamma analysis was used and compared with the new gamma analysis criteria. The results showed that mean γ of aS1200 EPID are likely to the

Table 1. The percent gamma passing rate results of aS1200 EPID and PTW Octavius 1500 for FF and FFF beams.

Device	Criteria	FF			FFF		
		γ	S.D.	p-value	γ	S.D.	p-value
aS1200	3%/3mm	98.37%	2.01%	0.000	99.67%	0.49%	0.001
OD1500		99.73%	0.66%		99.86%	0.30%	
aS1200	3%/2mm	97.39%	3.14%	0.034	99.35%	0.82%	0.233
OD1500		98.50%	1.95%		98.82%	1.75%	

results from PTW Octavius 1500 for 3%/3mm and 3%/2mm criteria. However, the difference was not statistically significant (p-value > 0.05) only 3% DD/2mm DTA of FFF beams, as shown in table 1.

The patient specific QA in FF and FFF were comprehensively analyzed using

the arc-by-arc method. **Figure 2** shows the patient specific QA results in FF beams. Thirty verification plans with eighty three arcs were compared between the measurements from aS1200 EPID with PTW Octavius 1500 using gamma analysis of 3%/2mm, global normalization with 10% dose threshold. The results showed that

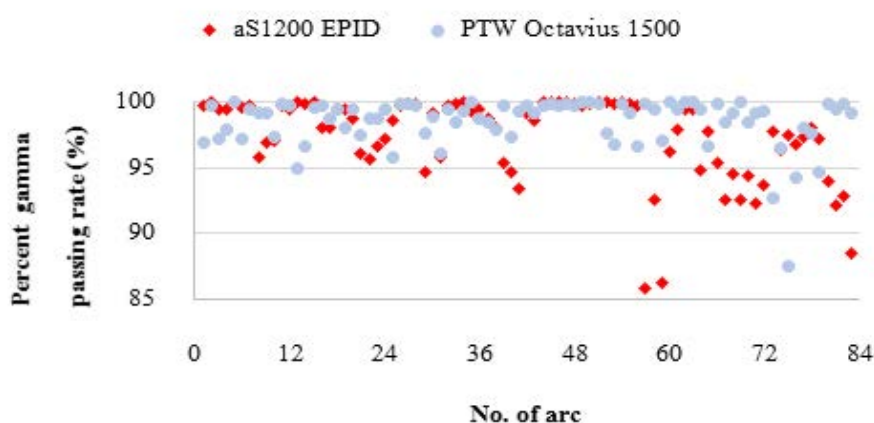


Figure 2. The percent gamma passing rate of aS1200 EPID and PTW Octavius 1500 for 3%/2mm gamma index with 10% dose threshold of FF plans.

most of γ of aS1200 EPID measurements for arc-by-arc were lower with greater SD value from PTW Octavius 1500 results. The minimum gamma passing rate of aS1200 EPID was 85.8% while the results from PTW Octavius 1500 was 87.5%.

The patient specific QA for FFF beams technique was also comprehensively evaluated. Thirty verification plans with eighty two arcs were compared with the results from the measurements using PTW Octavius 1500. The new gamma index criteria (3%/2mm) was used for analyzing the results. **Figure 3** shows the percent gamma passing rate results from aS1200 EPID and PTW Octavius 1500 measurement. The results showed that the percent

gamma passing rate from aS1200 EPID were slightly higher than the results from PTW Octavius 1500 with a lower spread out data. The minimum gamma passing rate of aS1200 EPID was 95.5% while the results from PTW Octavius 1500 was 90%.

A traditional gamma index criteria vs new gamma index criteria

All sixty patient's VMAT verification plans with a total of 165 arcs were measured. The mean and SD of the γ were used for evaluation of the results. The results of the test are shown in **figure 4**.

For 3% DD/3mm DTA, the mean percent gamma passing rate $\pm$ SD of aS1200 and PTW Octavius 1500 were 99.02% $\pm$

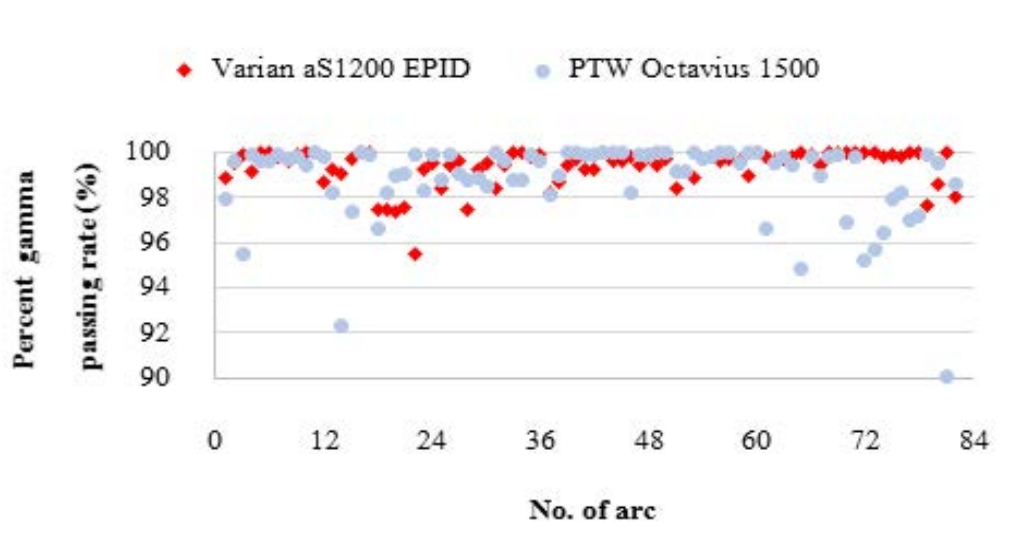


Figure 3. The percent gamma passing rate of aS1200 EPID and PTW Octavius 1500 for 3%/2mm gamma index with 10% dose threshold of FFF plans.

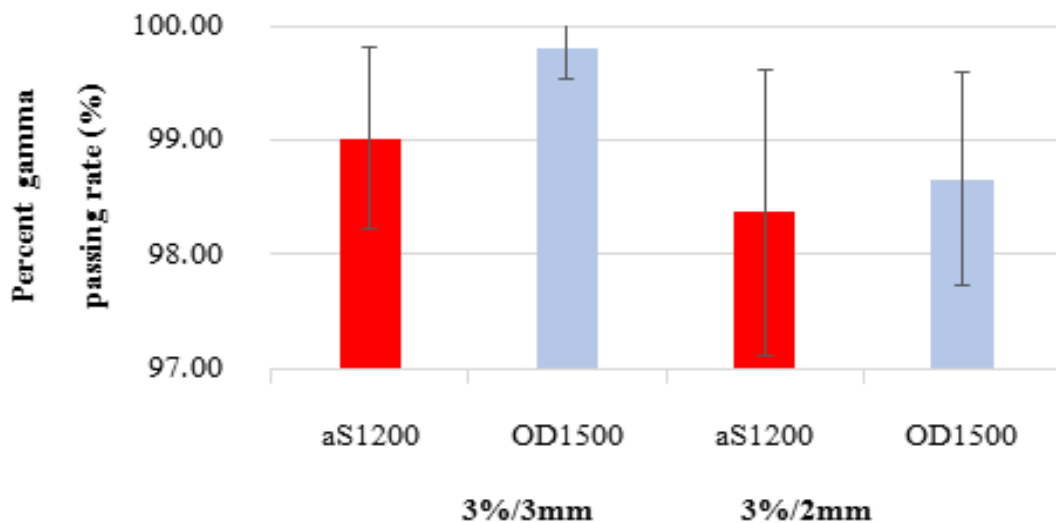


Figure 4. The mean gamma passing rate of aS1200 EPID and PTW Octavius 1500 for a global normalization with 3%/3mm and 3%/2mm gamma analysis criteria for a 10% dose threshold.

1.60% and $99.80\% \pm 0.52\%$ (p-value = 0.000), respectively. For 3% DD/2mm DTA, the mean percent gamma passing rate $\pm$ SD of aS1200 and PTW Octavius 1500 were $98.36\% \pm 2.50\%$ and $98.66\% \pm 1.86\%$ (p-value = 0.416), respectively.

Discussion

About the patient specific QA implementation of aS1200 EPID for FF and FFF beams, we studied aS1200 EPID and compared the results with PTW Octavius 1500. The γ results of the study showed that most of the γ results from PTW Octavius 1500 were slightly higher than aS1200 EPID because PTW

Octavius 1500 used 3D gamma analysis, while aS1200 EPID used 2D gamma analysis, so the effect from 2D and 3D gamma analysis have proposed from elsewhere^[11].

Another reason which affected to the γ results were the method to configure the Portal Dosimetry. In our configured verification process based on the standard method, as described by Van Esch et al.^[12], the percent gamma passing rate results of the AIDA plan which planned by FF beams (6 and 10 MV) was dropped and showed red dot in large area, yet did not present in FFF plans, as shown in **figure 5 (A) and (B)**. However, this results occurred in another institute where uti-

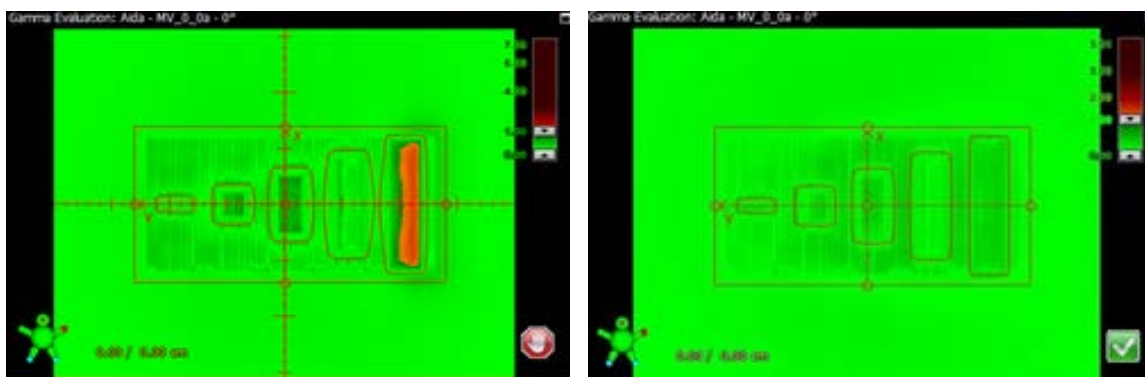


Figure 5. The gamma evaluation result of AIDA pattern. (A) 10 MV FF beams and (B) 10 MV FFF beams.

lizes Varian EDGE LINAC with aS1200 EPID (Varian Medical System, Palo Alto, CA) too (private communication). Therefore, the mean γ and SD of the FF plans which measured by aS1200 EPID are worse than the other detector for both criteria, as shown in table 1 and figure 2. In the other hand, the mean γ and SD of aS1200 EPID for FFF plans which did not have the issue from the configuration process showed that the γ and SD from both detectors were likely to each other and especially greater results for FFF plans at the new gamma index criteria, as shown in table 1 and figure 3. This is able to conclude that aS1200 EPID is able to do a patient specific QA in FF and FFF beams without any special condition. The detector resolution may be dominated factor in stringent gamma criteria, which increased percent

gamma passing rate of aS1200 EPID, as shown in table 1.

The effects of the stringent criteria are shown in figure 4. The results showed $0.66\% \pm 0.90\%$ decreasing of the gamma passing rate from aS1200 EPID when using the new gamma criteria, while the percent gamma passing rate of PTW Octavius 1500 decreased by $1.14\% \pm 1.34\%$, which indicated that PTW Octavius 1500 was more sensitive to the stringent gamma analysis criteria than aS1200 EPID. These results might be caused by the spatial resolution for each detector. Beyer et al.^[13] studied aS1200 EPID for the pre-treatment patient specific QA in prostate and head & neck plans, which planned by FF and FFF beam techniques, comparing with PTW Octavius 1500 by using gamma analysis with 2%/2mm and

10% dose threshold criteria. The results showed that aS1200 EPID had slightly better gamma passing rate than PTW Octavius 1500 because aS1200 EPID has higher spatial resolution than PTW Octavius 1500, as the same way to our results. Therefore, the difference between aS1200 EPID and PTW Octavius 1500 was not statistically significant ($p\text{-value} > 0.05$) in 3%/2mm criteria ($p\text{-value} = 0.416$). It is able to indicate that aS1200 EPID plays a critical role to do a patient specific QA in the new gamma index criteria.

Conclusion

The new version of Varian EPID, aS1200 EPID, is an effective tool for a patient specific QA due to its performance such as high spatial resolution, ease of use and reduction of QA time that is able to decrease medical physicists' workload. As a result from the study, it is able to

conclude that aS1200 EPID is not only suitable for QA using a new gamma index tolerance, which was proposed by AAPM TG-218, but also performs a patient specific QA for a verification plan of flattening filter free technique with the comparable results to PTW Octavius 1500 planar ionization chamber detector. Therefore, aS1200 EPID is a powerful detector for a patient specific QA in both FF and FFF beams, especially in the busy department of radiation oncology.

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