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# RapidArc treatment planning quality assurance using electronic portal imaging device for cervical cancer

Hafiz Muhibb ullah Zulkafal[1,2], Allah Ditta Khalid[3], Sajid Anees Minhas[2], Umair Zafar[2], Rizwan Hameed[2], Muhammad Afzal Khan[1] and Khalid Iqbal[1,2]

[1]Department of Physics, The Islamia University of Bahawalpur, Bahawalpur, Pakistan; [2]Department of Clinical and Radiation Oncology, Shaukat Khanum Memorial Cancer Hospital and Research Centre Lahore, Lahore, Pakistan and [3]Department of Physics, University of Lahore, Lahore, Pakistan

**Original Article**

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**Author for correspondence:**
Hafiz Muhibb ullah Zulkafal, Department of Physics, Baghdad Al Jadeed Campus, The Islamia University of Bahawalpur, Punjab, Pakistan. Tel: +92-3024388245. E-mail: muhibbiub@yahoo.com

## Abstract

*Purpose:* The main objective of this study is to assure the quality of cervical cancer treatment plans using an electronic portal imaging device (EPID) in RapidArc techniques.
*Materials and Methods:* Fifteen cases of cervical cancer patients undergoing RapidArc technique were selected to evaluate the quality assurance (QA) of their treatment. The computed tomography (CT) of each patient was obtained with 3-mm-slice thickness and transferred to the Eclipse treatment planning system. The prescribed dose (PD) of 50·4 Gy with 1·8 Gy per fraction to planning target volume (PTV) was used for each patient. The aim of treatment planning was to achieve 95% of PD to cover 97%, and dose to the PTV should not receive 105% of the PD. All RapidArc plans were created using the AAA algorithm and treated on Varian DHX using 6 MV photon beam, with two full arcs. Gamma analysis was used to evaluate the quality of the treatment plans with accepting criteria of 95% at 3%/3 mm.
*Results:* In this study, maximum and average gamma values were 2·53 ± 0·409 and 0·195 ± 0·059 showing very small deviation and indicating the smaller difference between both predicted and portal doses. Gamma Area changes from > 0·8 to > 1·2. SD increased to 5·4% and mean standard error increased to 4·67%.
*Conclusion:* On the basis of these outcomes, we can summarise that the EPID is a useful tool for QA in standardising and evaluating RapidArc treatment plans of cervical cancer in routine clinical practice.

## Introduction

Radiotherapy treatment requires quality assurance (QA) programs as it uses ionising radiations. QA in radiotherapy treatment provides patient safety and avoidance of accidental unnecessary exposure.[1] Volumetric modulated arc therapy (VMAT) is the advanced version of intensity-modulated radiation therapy (IMRT) that can deliver the dose precisely on target volumes with more than one arc and provides dose delivery with gantry-arc and gantry-speed modulations.[2] The Varian version of VMAT is RapidArc, which was developed by Karl Otto in 2008, and it utilises dose painting techniques for increasing dose per fraction to the target site.[3–5] For the treatment of head and neck cancer, Mohan et al. used simultaneous integrated boost (SIB) in IMRT that showed the advantages of shorter treatment time, improved conformity of target and reduced doses to Organs at Risk (OARs) as well as better dose hotspot control.[6] Jin et al. utilised SIB in VMAT for nasopharyngeal cancer and proved that two-arcs SIB VMAT is better for target coverage with significantly shorter delivery times, but it showed no improvement for doses to the OAR.[7] Stieler et al. have performed comparison of different techniques in terms of dosimetric validation for head and neck cancer and proved that VMAT is the most efficient treatment option affording a high degree of treatment complexity.[8] Guckenberger et al. revealed that single-arc VMAT has improved the target coverage and dose homogeneity in radiotherapy for prostate cancer. Also multiple-arc VMAT improved the results compared to single-arc VMAT.[9]

The use of VMAT has now been adopted as a technique to treat cervical cancer. Cervical cancer is considered as one of the most commonly occurring gynaecologic cancer, and 83% of cases are found in the developing countries.[10] In cervical cancer treatment, pre-treatment QA is essential for VMAT: the most commonly practised measurements of absolute dose are made using ionisation chambers and diodes, and these measurements are combined to make isodose distribution measurements in a phantom.[11–13] Patient-specific QA in VMAT is mainly achieved using an electronic portal imaging device (EPID) and two-dimensional (2D) array ion chambers for dose verification.[14] Radiation beam delivery to planning target volume (PTV) needs QA before treatment for each plan using portal dosimetry or 2D array.[15,16] For



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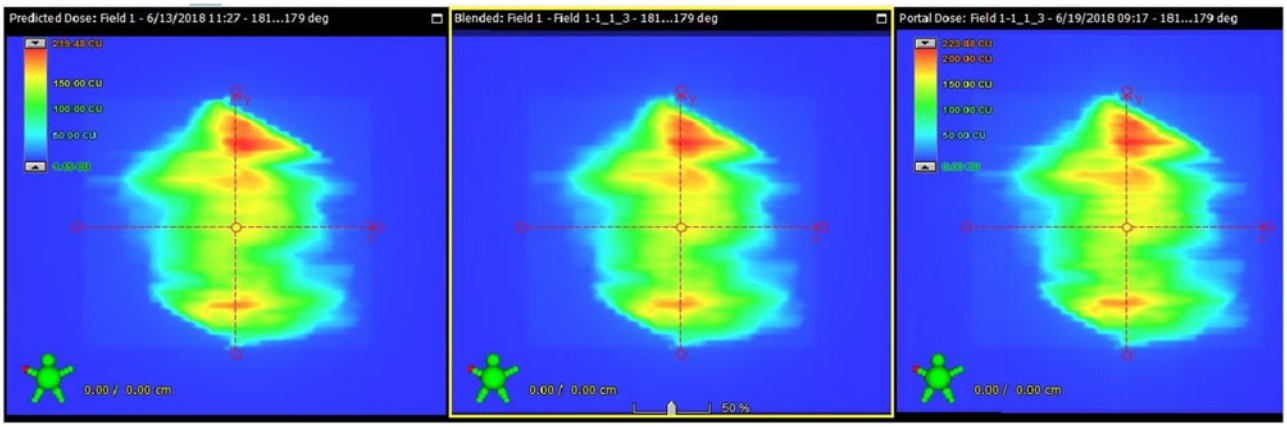


**Figure 1.** VMAT plane delivery portal. Abbreviations: VMAT, volumetric modulated arc therapy.

VMAT treatments, the scheduled dosimetric verification of fields is important.[17] The concept of distance to agreement (DTA) criterion for comparison of dose distribution is performed by gamma evaluation method. DTA is actually the distance of reference point and closest data point in the compared dose distribution.[18] Software is utilised to acquire gamma index (GI) evaluation in which maximum and average dose deviation between measured and calculated plan are observed.[19] Portal dosimetry is a good option and can be applied directly to verify measured dose distribution that provides comparison of doses: portal dose prediction (PDP) and the dose calculated from the treatment planning system (TPS). Consequently, portal dosimetry provides verification of the treatment plan.[20,21] In the current study, we have adopted the acceptance level of plane only when both dose difference (DD) and DTA criteria are fulfilled. Normally, DD 3% or DTA 3 mm is adopted for daily basis QA for each plan, but in this project we have selected 3% of 3 mm for dose distribution verification of RapidArc treatment plan. We have used $\gamma$ analysis software for the comparison of calculated and measured dose distribution of RapidArc treatment plans. Tolerance values of gamma evaluation are, for area $\gamma$ <1·0 = 97%, Average $\gamma = 0{\cdot}50$ and Maximum Gamma= 3·50.[22] All these dosimetric parameters are evaluated using EPID for RapidArc treatment plans of cervical cancer to improve clinical practice.

## Materials and Methods

Fifteen cases of cervical cancer treated with RapidArc technique in Shaukat Khanum Memorial Cancer Hospital & Research Centre Lahore in June 2018 are included for consideration of QA. All these cases were selected randomly, patients were informed and signed consents were obtained. Patients' ages ranged from 38 to 70 years, and for all these patients, dose distribution measurements of plans for dosimetric purpose have been made using EPIDs. EPIDs were initially adopted for patients' positioning, but now it has also gained importance in field verification and obtaining dosimetric information.[23]

Figure 1 shows predicted dose at left, portal dose at right and central part shows the dose map delivered to patient after approval. EPID has become the essential part of TPS and provides calculated and measured dose comparison. In this project, the EPID protocol is used to verify the RA treatment.

Computed tomography (CT) simulation of each patient with oral and intravenous contrast is obtained using AQUILION 16-slice spiral CT scanner (Toshiba America Medical Systems, Inc., USA) with 3-mm slice thickness. These images of each patient are transferred to TPS for treatment planning consideration. For uniqueness, all those plans have been selected which are made by the same radiation oncologist. In all these plans, he defined gross tumour volume (GTV) and clinical target volume (CTV). Besides, he delineated the doses for bladder, small bowel, rectum and femoral heads. CTV includes entire uterus, potential microscopic disease, regional lymph nodes, parametrial tissues and upper half of the vagina. By including 8 mm all in directions to CTV, the PTV is archived. The prescribed dose (PD) of 50·4 Gy with 2 Gy per fraction is used according to the treatment protocol described by different studies and is in practice.[24] These plans are normalised to achieve mean dose to PTV. Moreover, 95% of PD should cover 97% of PTV and should not cross 105% of maximum dose.

Figure 2 shows dose statistics of PTV and OARs. The OARs included in this study are small bowel, rectum, bladder and femoral heads. Constraints applied in this project are listed as: the volume receiving 40 Gy of radiation were <40% for the rectum, <50% for the bladder, <25% for the small bowel and <5% for the femoral heads.[24] In all these RapidArc treatment plans, collapsed cone beam convolution algorithm is adopted and Varian Clinac® DHX (Varian Medical Systems, Palo Alto, CA) is utilised for 6 MV photon beam, with two clockwise rotating full arcs of 120 leaf of multileaf collimator (MLCs) and 178 control points. For each control point, cumulative dose gantry angle and the position of each MLC leaf are specific.

The plan is delivered by treatment console and MLC controller by controlling dose versus gantry angle and controlling the MLC position versus gantry angle, respectively. The two-arc treatment plan of RapidArc with dose distribution is shown in Figure 3. Gamma analysis in Eclipse software provides comparison of images and pixels. ARIA 11 Eclipse TPS and Varian DHX having EPID with specifications: amorphous Silicon (aSi) detector technology, a resolution of 512 × 384 pixels, maximum resolution of 1,024 × 768 with aSi active detector area of 30 × 40 $cm^2$. In the current project, after studying practised and dosimetrically approved plans, we have selected DD 3% and DTA 3 mm passing criteria for plans of 95% dose.[25] In spite of concurrence, there are different recommendations of DD/DTA passing criteria presented by different groups. TG 119 proposed 3%/3 mm for 90% passing criteria, and ESTRO recommended passing criteria for 95% dose should have tolerance 4%/3 mm.[26,27] In this project, confidence interval (CI), lower confidence limit (LCL) and upper confidence limit (UCL) in terms of count units (CU) for DD are also calculated.[28]

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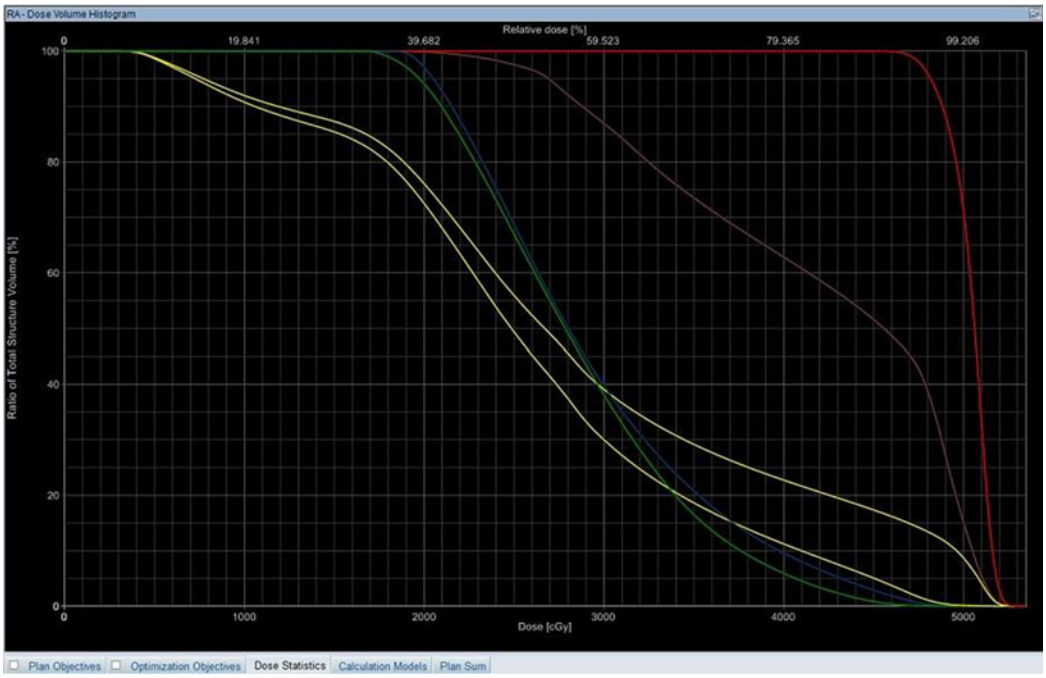


**Figure 2.** Dose volume histogram.

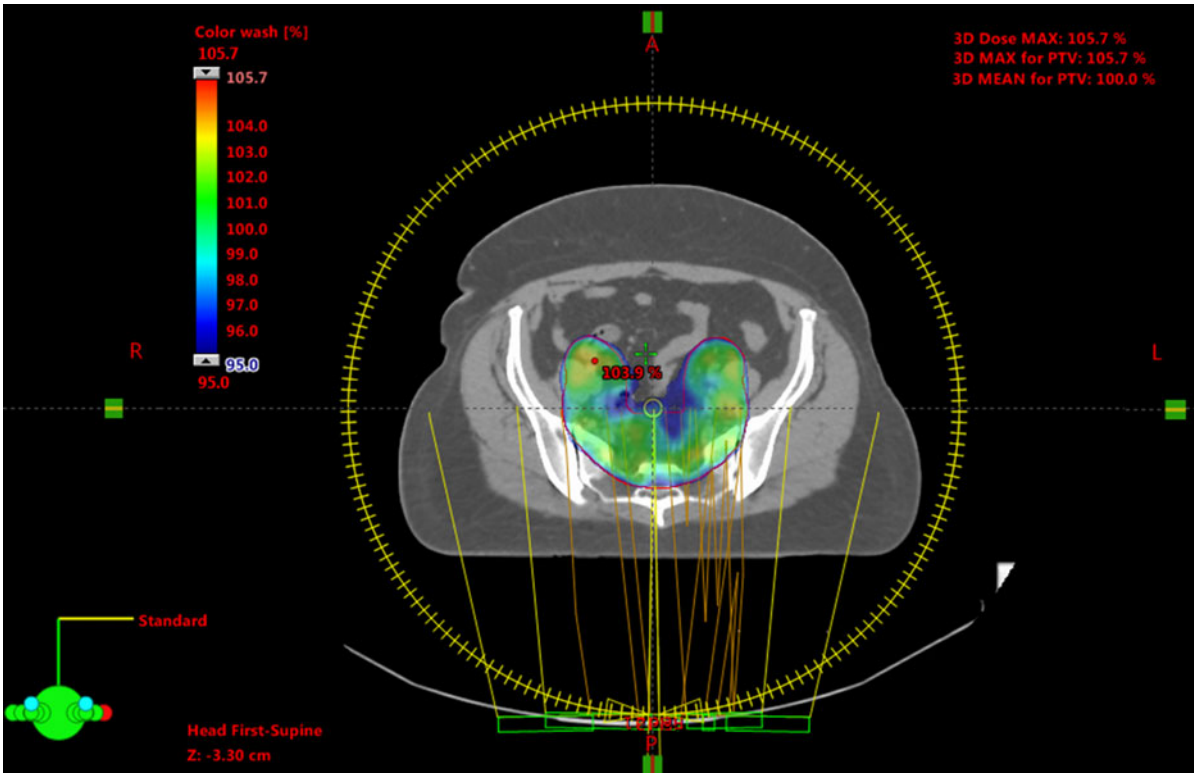


**Figure 3.** 7 Field VMAT treatment plan. Abbreviations: VMAT, volumetric modulated arc therapy.

## Results

In TPS, gamma evaluation software automatically generates the values of area gamma <1, area gamma > 0·8, area gamma >1·2, average gamma values and the values of maximum gamma. The last two aforementioned parameters, average $\gamma$ and maximum $\gamma$ that are 99$^{th}$ percentile of gamma distribution for 2D gamma evaluations are compared with EPID.

We selected the limits for maximum and average $\gamma$ values to be 3·50 and 0·5, respectively. These limits set by our institution were strictly obeyed. Additionally, the minimum deviation will appeal

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**Table 1.** Statistical values for maximum gamma and average gamma

| Cervix | Maximum gamma | Average gamma |
|---|---|---|
| Mean value | 2·53 | 0·195 |
| SD | 0·490 | 0·059 |

**Table 2.** Dose values for 95% confidence values

| Cervix | $\gamma$ Criteria 3%/3 mm | DD in CU |
|---|---|---|
| Mean value | 98·046 | 2·11 |
| SD | 1·34 | 0·86 |
| LCL | 97·37 | 1·67 |
| UCL | 98·72 | 2·55 |
| CI | ±0·68 | ±0·44 |

*Abbreviations*: DD, dose difference; CI, confidence interval; LCL, lower confidence limit; UCL, upper confidence limit.

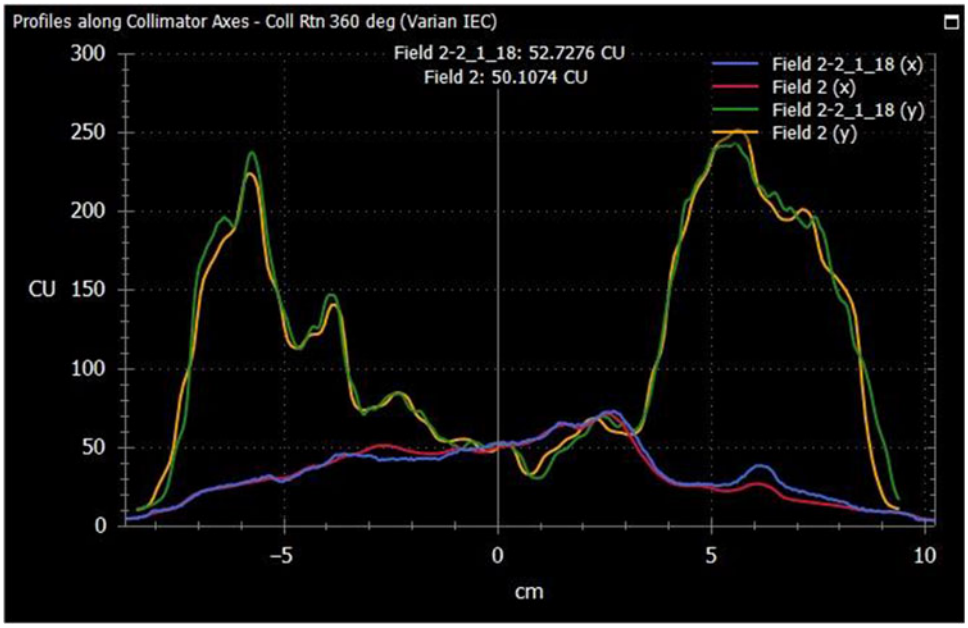


**Figure 4.** Dose distribution along *X* and *Y* axes in comparison.

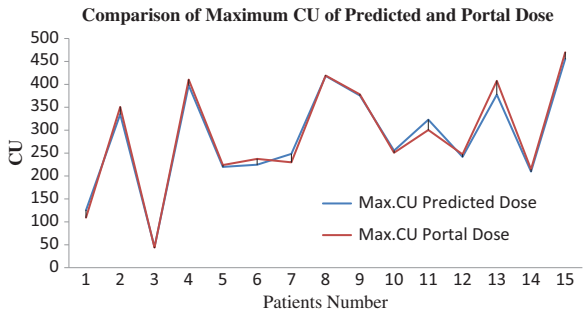


**Figure 5.** Comparison of maximum count units in predicted and portal doses.

the further amendments in the plan before acceptance. Table 1 represents the mean values and SD for 15 RapidArc cases. In this research, maximum and average gamma values were 2·53 ± 0·409 and 0·195 ± 0·059, respectively, for 3%/3 mm passing criteria. These values show very small deviation and indicate the smaller difference between both predicted and portal doses. Another feature of EPID software is to delineate dose map in the form of graph.

Portal dosimetry shows pictorially the dose distribution for both predicted and portal doses by two sets of lines along *X* axes and *Y* axes as shown in Figure 4. Perfection in dose delivery spares the OARs for each critical site of cancer treatment by radiotherapy.[29]

Figure 5 shows the graphical comparison of maximum count units for each case between portal dose and predicted dose, and no large mismatching of the two lines is seen.

When area gamma changes from > 0·8 to > 1·2, it is seen that the SD increases 5·4% and standard error of mean increases 4·67%. In Figure 6, it is seen that when the range of area gamma increases, DD values decrease, and SD and standard error of mean indicating precision of dose distribution decrease.

Table 2 shows the mean $\gamma$ pass rate 98·05% ± 1·34. For the verification of RapidArc plans, UCL and LCL with CI on the basis of normal distribution of GI and DD are discussed. CI has been calculated using the relation

$$X \pm Z\, s\sqrt{n}$$

$X$ is the mean value; we set the confidence level value of 95%, according to the statistical chart, $Z = 1{\cdot}960$. $S$ and $n$ represent SD and number of cases for each calculation, respectively. Our observation shows 98·046, 95% CI [97·4, 98·7] with margin of error: 0·678 for $\gamma$ criteria 3%/3 mm. The same test is applied for DD values and found 2·11, 95% CI [1·67, 2·55] with the margin of error to be 0·44.

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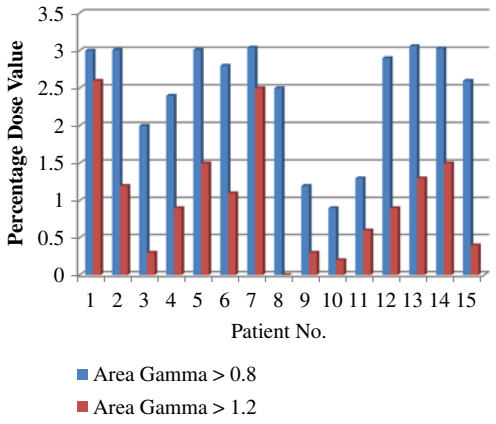


**Figure 6.** Comparison of two values of gamma area.

## Discussion

In routine QA, portal dosimetry provides a good way to improve radiation therapy treatment. In spite of its frequent use, there are no clear trends in agreement between portal dose and measured dose. We have selected 15 plans of RapidArc radiation treatment technique and evaluated two scalar parameters: maximum gamma and average gamma. Their values in this work were 2·53 ± 0·409 and 0·195 ± 0·059, respectively, for 3%/3 mm passing criteria. These values show very small deviation and indicate the smaller difference between both predicted and portal doses as shown in Table 1. From Table 2, we can see that these RapidArc treatment plans on the average 98·05% of the pixels passed the criteria of 3%/3 mm with SD of 1·34. Then these data values were used to set clinical action based on the mean and SDs set by the institute. It is found that agreement between measured dose and PDP was improved by recalculating the fields at lower dose rates.[30] Figure 5 illustrates the difference of maximum CU of predicted and portal doses, and it is clear in only one case in which more than 450 CU were used. Two cases contain more than 400 CU and all the other had used lower values. In Figure 6, it is seen that the range of area gamma when increases, SD and standard error of mean increases that indicates precision of dose distribution decreases. These methods of verification are only applicable in routinely practised field sizes; field sizes greater than $30 \times 30$ cm$^2$ cannot be verified by using these techniques. By applying these methods of treatment plan verification, the routine clinical practice can be improved for cervical cancer.

## Conclusion

Having uncompromised target coverage in short delivery time, RapidArc treatment technique has proved as an enhanced technique for sparing healthy tissues and OARs. The present results provide the need of reasonable and achievable standard for RapidArc treatment planning QA. On the basis of these results, we can conclude that EPID is a useful tool as QA device for standardising and evaluating RapidArc-based treatment plans in the routine clinical practice, especially for cervical cancer.

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