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Verification of Extended Source-To-Imager Distance (SID) Correction for Portal Dosimetry

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This study aimed to evaluate and verify a process for correcting the extended source-to-imager distance (SID) in portal dosimetry (PD). In this study, eight treatment plans (four volumetric modulated arc therapy and four intensity-modulated radiation therapy plans) at different treatment sites and beam energies were selected for measurement. A Varian PD system with portal dose image prediction (PDIP) was used for the measurement and verification. To verify the integrity of the plan, independent measurements were performed with the MapCHECK device. The predicted and measured fluence were evaluated using the gamma passing rate. The output ratio was defined as the ratio of the absolute dose of the reference SID (100 cm) to that of each SID (120 cm or 140 cm). The measured fluence for each SID was absolutely and relatively compared. The average SID output ratios were 0.687 and 0.518 for 120 SID and 140 SID, respectively; the ratio showed less than 1% agreement with the calculation obtained by using the inverse square law. The resolution of the acquired EPIDs were 0.336, 0.280, and 0.240 for 100, 120, and 140 SID, respectively. The gamma passing rates with PD and MapCHECK exceeded 98% for all treatment plans and SIDs. When autoalignment was performed in PD, the X-offset showed no change, and the Y-offset decreased with increasing SID. The PD-generated PDIP can be used for extended SID without additional correction.

Keywords: Portal dosimetry, PDIP, Extended SID, VMAT

Introduction

In radiotherapy, delivery techniques have been improved considerably to deliver highly conformal dose distributions.[1] Intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) techniques can provide prescription doses to target volumes while avoiding normal tissue complications.[2,3] These modern techniques by utilizing beam modulations (i.e. MLC positions, gantry rotation speeds, and dose-rates) increased the complexity of delivery methods and involve large uncertainties.[4] Therefore, patient-specific quality assurance (QA) should be performed prior to the first treatment fraction for a patient being treated with IMRT or VMAT.[5-7]

In recent years, electronic portal imaging device (EPID) has been introduced for patient-specific dosimetry owing to the high resolution, temporal stability, negligible set-up time, and proven high accuracy.[8] Portal dosimetry (PD) is one of the methods used to evaluate measured fluence using an EPID.[9] PD was proven to be clinically effective in previous research.[10-12] PD has been established utilizing EPID for pretreatment verification.[13,14]

Modern radiotherapy has increased the need for online dose verification owing to the complexity and accuracy of the new delivery techniques. (e.g., VMAT or Stereotactic ablative radiotherapy (SABR)).[15] Several studies have reported the in vivo EPID dosimetry for IMRT and VMAT.[10,16] They reported the successful clinical implementation of real-time verification using EPIDs.[17]

In general, the EPID is located at the isocenter (i.e., source-to-imager distance (SID)=100 cm) for pretreatment verification.[18] For in vivo treatment, the EPID should be placed at an extended SID to avoid the collision of the EPID and patient. However, calibration and portal dose image prediction (PDIP) configuration are performed for SID=100 cm. In the case of extended SID, the resolution of the measured dose distribution is different from the predicted dose distribution. The predicted dose was generated at the reference distance (i.e., SID=100 cm).[19] Therefore, the measured dose should be corrected by a magnification factor according to SID.[20]

In this study, we performed the PD with various SIDs to evaluate the dose distribution and absolute dose measurement for SIDs. We compared measurement obtained for reference condition with those at various SIDs. The effect of SID on PD was evaluated.

Materials and Methods

We selected four IMRT and four VMAT plans of Vital with Millennium 120 MLC (Varian Medical Systems, Palo Alto, CA, USA) with 6 MV, 6 flattening filter free (FFF), 10 MV, and 15 MV beam. The treatment sites were the lung, brain, spine, liver, and pelvis. All the plans were generated by Eclipse using Acuros XB algorithm (ver. 13.7, Varian Medical Systems, Palo Alto, CA).

The verification plan of each plan was generated for PD (ver. 13.7, Varian Medical Systems, Palo Alto, CA). PD was generated based on PDIP for each SID. MapCHECK2 (Sun Nuclear Corp., Melbourne, FL, USA) dosimeter with MapPHAN^{TM} (Sun Nuclear Corp., Melbourne, FL, USA) was used as a 2D-array dosimeter for the verification of plan integrity.

For PD, the fluence map was obtained using aS1200 EPID at 100 cm, 120 cm, and 140 cm SID. The EPID was supported by the arm. The area of the active layer was 43×43 cm^2, with 1280×1280 pixel resolution. The EPID was calibrated in the dosimetry acquisition mode at 100 cm SID. Dark and flood-field correction was applied for absolute calibration with a 10×10 cm^2 field. The calibrated unit (CU) was defined as 100 MU to correspond to 1 for each aSi detector.

MapCHECK2 dosimeter has 1527 diode detector, which is of the size 0.8×0.8 mm^2, with 7.07 mm spacing, and 50 ms sampling rate. The field size of MapCHECK2 is 32.0×26.0 cm^2.[21] MapPHAN is made of a water equivalent material with a mass density of 1.05 $g.cm^{-2}$ for rotational dosimetry.

The measured dose with the EPID was analyzed with the predicted dose generated by PDIP (ver. 13.7, Varian Medical Systems, Palo Alto, CA) in PD of ARIA (ver. 13.7, Varian Medical Systems, Palo Alto, CA) console. SID output ratio was defined as the ratio of absolute dose of reference SID (100 cm) to the absolute does of each SID (120 or 140 cm). For PD, automated align adjustment was applied to check the center of measured fluence map.

The gamma passing rate was calculated for both PD and MapCHECK using SNC patients program. The global gamma evaluation was used with a normalization point selected in minimum difference point. For all the plans, the gamma criterion was 2%/2 mm. Point doses less than 10% of the maximum dose were excluded for gamma analysis.

Results

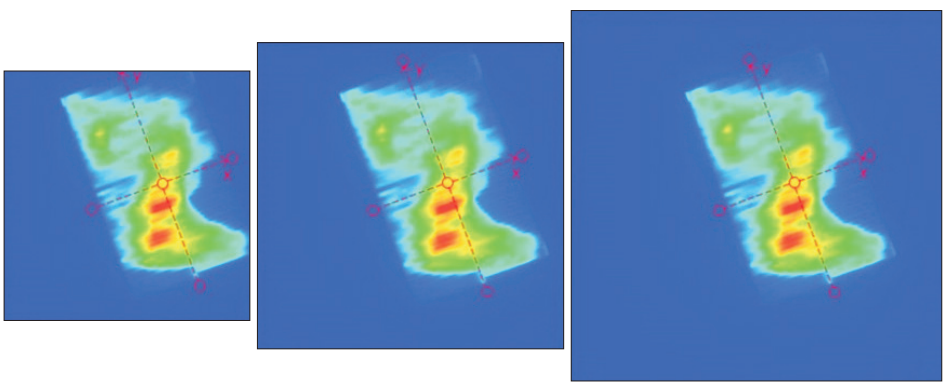
The average SID output ratio was 0.687 and 0.518 for 120 cm SID and 140 cm SID, respectively. For 120 and 140 cm SID, the ratios by the inverse square law were 0.694 and 0.510, respectively.

The resolutions of the acquired EPID were 0.336, 0.280, and 0.240 for 100, 120, and 140 cm SID, respectively.

Table 1 lists the used the energy, site, average X- and Y-offset, and gamma passing rate for each patient. The gamma passing rate was above 98% for all the SIDs. Fig. 1 shows the fluence distribution acquired by EPID for three SIDs. The size of the measured fluence was the same for all SIDs. However, the total area decreased as the SID increased. The absolute and relative dose profile at the measured center is shown in Fig. 2. The measured center was

Table 1 The energy, treatment site, SID, X and Y offset, and average gamma passing rate for each patient.

Patient	Energy	Site	SID (cm)	X offset	Y offset	Gamma passing rate (%)
1	6X	Lung	100	0.432	0.592	92.7
			120	0.262	0.407	93.6
			140	0.242	0.107	93.9
2	6X	H&N	100	0.392	0.582	99.5
			120	0.132	0.357	99.7
			140	−0.093	0.337	98.7
3	6XFFF	Lung	100	0.102	0.557	99.6
			120	−0.105	0.317	99.4
			140	0.125	0.227	99.9
4	6XFFF	Lung	100	0.101	0.557	99.9
			120	0.473	0.307	100
			140	0.027	0.267	100
5	10X	Prostate	100	0.137	0.657	99.6
			120	−0.033	0.332	100
			140	−0.243	0.222	100
6	10X	Pelvis	100	0.097	0.377	99.5
			120	−0.153	−0.013	99.9
			140	−0.438	−0.153	99.7
7	15X	Cervix	100	0.222	0.592	99.8
			120	0.022	0.342	99.9
			140	−0.163	0.202	99.6
8	15X	Abdomen	100	0.137	0.572	99.6
			120	−0.053	0.237	99.4
			140	−0.243	0.132	99.5



(a) SID: 140 cm **(b)** SID: 120 cm **(c)** SID: 100 cm

Fig. 1. Dose distribution acquired by electronic portal imaging device (EPID) in Portal dosimetry for (a) 140 cm, (b) 120 cm, and (c) 100 cm source-to-imager distance (SID).

automatically determined by the PD. The absolute dose profiles differed from the SID output ratio. The relative dose profiles almost had the same shape.

When MapCHECK was used for QA, the gamma passing rate of verification plan was over 95% for all the patients.

Discussion

In this study, the effect of SID on PD with PDIP was evaluated for three SIDs. As the reference condition, PD was performed at 100 cm SID. Extended SID setup is necessary on clinical demand, especially, to perform online dosimetry (i.e, in vivo verification), extended SID is required to

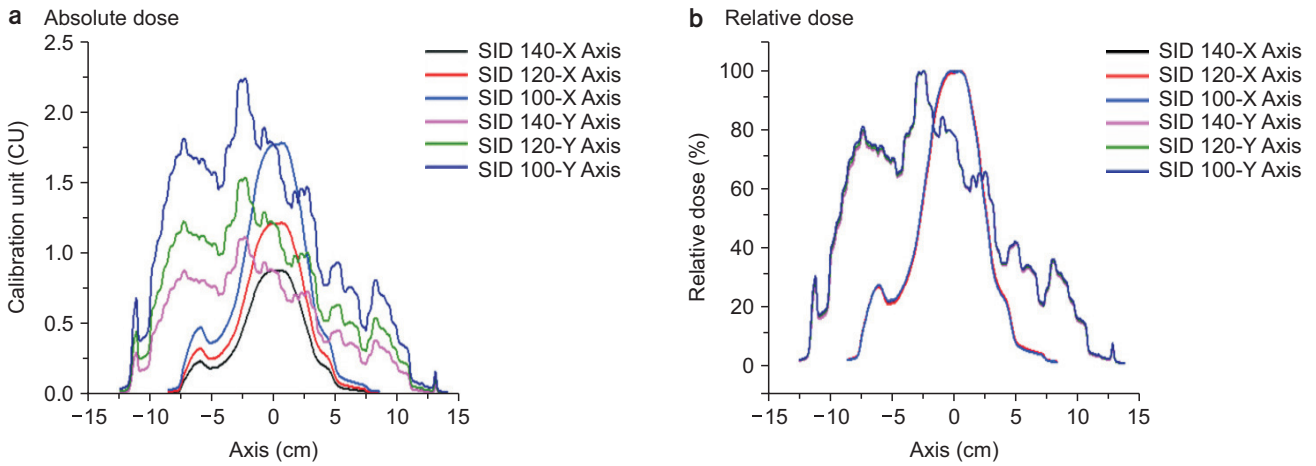


Fig. 2. (a) Absolute (b) and relative X- and Y-axis dose profile for 140 cm, 120 cm, and 100 cm source-to-imager distance (SID).

measure with the EPID when the beam is turned on. In general, absolute calibration and field calibration are performed at 100 cm SID. However, PD can be performed at an extended SID. Therefore, the evaluation of SID dependency is important.

For independent verification, patient-specific QA was performed with MapCHECK2 and MapPHAN. The gamma passing rate was above 95% for all analyses. The integrity of the plan was verified.

In PD, the gamma passing rate was above 98% with relative comparison for all of verification. The measured does with extended SID was projected to 100 cm SID with magnification factor. In addition, the predicted dose was also generated at extended SID and scaled down with the appropriate magnification factor. Therefore, the passing rate did not shown any correlation to SID.

As SID increased, the resolution of the acquired EPID became finer. The resolution of the fluence generated by MLC remained constant. The resolution of the projected fluence on the EPID for extended SID increased. The projected fluence reduced by the magnification calculated using the inverse square law. Therefore, in PD, the resolution was lower for extended SID.

The shift by auto alignment reduced as SID increased in the Y-direction. The resolution of the measured dose increased with the increase in SID. The resolution increased proportionally with SID. The dose distribution of the extended SID needed a small shift owing to the fine resolution. However, there was no offset in the X-direction. For VMAT or IMRT, the gantry was rotated during measurement. The EPID can be affected by gravitational forces. The effect of gravity in the X-direction is greater than in the Y-direction.

For the absolute comparison, CU was determined at 100 cm SID according to the standard procedure. The CU decreased according to the inverse square law. The corrected CU (by the inverse square law) at 100 cm SID showed a difference less than 1 % when compared with the standard CU. If PD is used for online dosimetry and the EPID is located at extended SID, the measured CU can be corrected by the inverse square law for absolute comparison.

However, in the case of the extended SID for the EPID, the field size can be limited. As 1200 detector can measure the 43×43 cm^2 at 100 cm SID. When the EPID was placed at 140 cm SID, the measurable field size was limited to 30.7×30.7 cm^2. For the head and neck or pelvic cancer, the field size of the treatment can be greater than the limited size. In this case, PD is impossible. However, such cases are rare in a real clinic.

Conclusion

We evaluated the effect of SID on PD for 100, 120, and 140 cm SID. The absolute dose and measured fluence were accurately corrected following the inverse square law. Therefore, the PD can be performed for extended SID without additional correction.

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Conflicts of Interest

The authors have nothing to disclose.

Availability of Data and Materials

All relevant data are within the paper and its Supporting Information files.

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