Research Article

EVALUATION OF POSITIONAL ACCURACY OF EPID USING IMRT GRATICULE PHANTOM IN EXTENDED SOURCE TO IMAGER DISTANCE SETUPS: FORMALISM OF QA

**Ranjit Singh[1,3]*., Teerthraj Verma[2]., Harpreet Singh Kainth[3], Chappe Ram[4]., Devinder Mehta[3].,
Bhupinder S. Rana[5]., Jangvir Singh Shahi[3] and Baljinder Singh[6]**

[1]Department of Radiotherapy, Post Graduate Institute of Medical Education & Research, Chandigarh, India
[2]Department of Radiological Physics, King George Medical University, Lucknow, U.P., India
[3]Physics Department, Panjab University, Chandigarh, India
[4]Department of Radiotherapy & Radiation Medicine, Banaras Hindu University, Varanasi, India
[5]Department of Diagnosis and Imaging, Post Graduate Institute of Medical Education & Research, Chandigarh, India
[6]Department Nuclear Medicine, Post Graduate Institute of Medical Education & Research, Chandigarh, India

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ABSTRACT

Purpose: The aim of the present study was to evaluate the utility of IMRT graticule phantom to check the positional accuracy of EPID (amorphous silicon flat panel detector, retractable arm) and to develop a quality assurance program for geometrical verification.
Method: The radiographic images of graticule phantom were acquired using computed tomography (CT) and beam shapes for desired dose distribution was generated using computer based treatment planning system (Ecllipse, version 8.6, Varian, Palo, alto, CA). A known shift of 0.5 cm, 1.0 cm and 1.5 cm were introduced in longitudinal, lateral and vertical directions, respectively w.r.t. treatment couch of medical linear accelerator. The EPID images were taken for each shift at different source to imager distance (SID) and beam orientations.
Results: The maximum and minimum shift between the expected and observed value in all the direction were found to be 3 mm and zero respectively. In longitudinal and vertical directions, maximum error of 2 mm was obtained for SID 179.9 cm and 149.9 cm, respectively, while in lateral direction the 2 mm maximum error was obtained for imager distance 149.9 cm and 179.9 cm. However, the maximum error of 3 mm was found to be most frequent in the longitudinal and vertical directions for SID 149.9 cm and 179.9 cm, respectively.
Conclusion: The methodology used in the present study is very effective to check the mechanical characteristic and consistency of the retractable arm EPID and can be used routinely in radiotherapy units. The effect of EPID sag due to gravity was not significant for detection of shift in patient's position.

INTRODUCTION

The recent advancement in radiotherapy techniques requires accurate dose delivery and reproducible patient's position setup during treatment execution. The benefits of advanced treatment modalities could only be derived if the planned and delivered dose distribution matches exactly with each other. A small mismatch between these two may results in increase normal tissue complications and decrease in the tumor control probability[1-4]. Earlier X-ray port films were used in radiotherapy treatment to verify day to day patient's setup

*Corresponding author: **Ranjit Singh**
Department of Radiotherapy, Post Graduate Institute of Medical Education & Research, Chandigarh, India

which was time consuming and labor intensive and hence reduces patient throughput in the busy radiotherapy centre.[5] The introduction of electronic portal imaging device (EPID) in radiotherapy overcomes these problems. These are used for verification of patient position as well as dosimetric verification in complex radiotherapy modalities, e.g., intensity modulated radiotherapy (IMRT), image guided radiotherapy (IGRT) etc.[6-7] and quality assurance (QA) of medical linear accelerator. These treatment modalities (IMRT, IGRT) delivers non-uniform dose fluence with rapid dose fall off at the edge of the tumor volume. EPID is very effective for in-vivo dose measurements for such type of treatment[8-9] and the data analysis is rapid because of faster image acquisition and greater spatial resolution.[10] The task of multiple images, intra and inter-fractional assessment, or quantitative analysis of 3D treatment setup parameters were easily performed using

EPID.[11-12] The increase in frequency of imaging reduces the day to day patient error and hence improves the treatment precision.[12] The successful implementation of EPID in clinical oncology requires careful and regular QA and maintenance of EPID devices.[13] The QA of linear accelerator, e.g., performance, positional accuracy, inter and intra leaf radiation leakage of multi leaf collimators (MLC), field size verification, jaws position and orthogonality check etc. were also performed using EPID. The exclusive use of EPID - based QA tools, including a QA phantom and simultaneous analysis software tools has been demonstrated as a viable, efficient, and comprehensive process for daily evaluation of LINAC performance.[14] The commercially available EPID technology system consist of either matrix ion chamber or camera-based EPIDs or latest introduced active matrix flat panel imaging (AMFPI) and their properties are extensively studied by different authors.[15-18] The aim of the present study is to evaluate the utility of IMRT graticule phantom to check the positional accuracy of EPID (amorphous silicon flat panel detector, retractable arm) and develop a QA program for geometrical verification.

MATERIAL AND METHOD

In the present work, a Medical Linear Accelerator (Linac), Clinac DBx -1160 (Varian, Palo, alto, CA) from Varian medical system (Fig.1) having photon energy of 6 MeV was used. The Linear Accelerator[19-20] is equipped with a-Si 500 portal vision image detectors attached to the machine by retractable supporting arm (R-arm) for portal imaging.

Description of QA Test

The IMRT graticule phantom was placed on the couch of Computed Tomography (CT) simulator and three lead ball markers were placed on the respected faces at the point of intersection of all the three lasers (longitudinal, vertical and horizontal). The radiographic images of the phantom were acquired on the CT simulator with slice thickness of 2.5 mm. These CT images were sent to the planning system through digital communication (DICOM) and treatment plan was made using PBC algorithm.

The setup fields for anterior, left lateral and right lateral portal images were added to the existing plan. Digitally reconstructed radiographs (DRR) of the phantom were generated for each setup field on the TPS system (eclipse) and were considered as reference images. IMRT phantom was placed on the couch of the machine in a position reproducible as during the time of CT image acquisition. The appropriate shift obtained from the TPS plan was applied in longitudinal, lateral and vertical directions, so that the centre of irradiated volume coincides with machine isocentre. This position was considered as the reference position of the given IMRT phantom. The EPID images were taken for anterior, left lateral and right lateral setup of the same phantom. For a patient laid down in supine or prone position, the anterior portal image will give variation in the lateral (x-axis) and longitudinal (y-Axis) direction while the left lateral and right lateral portals give changes in the longitudinal and vertical
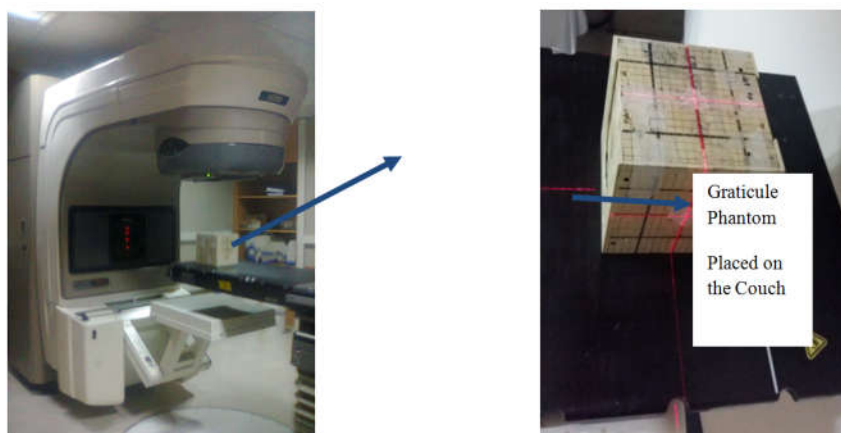

Fig. 1 Experimental setup (I) showing graticule phantom (II) placed over treatment couch of Clinax DBX-1160 along with inbuilt portal vision A-Si 500 (supported with retractable arm) for acquiring radiographic images.

The computer based treatment planning system, Ecllipse (version 8.6) uses pencil beam convolution (PBC) [21-22] and analytical anisotropic algorithms[23-24] with selective calculation grid size. The beam shapes and desired dose distributions are generate with the aim to maximize tumor control and minimize normal tissue complications. IMRT graticule phantom used in the present study was made up of tissue equivalent material and has a dimension of 18 cm × 18 cm × 18 cm. This phantom is quite useful to carry out X-ray port film dosimetry for various treatment modalities where the dose distribution is very complex. This phantom is provided with inbuilt graticule which is made up of radio-opaque markers and clearly visible in radiographic images.

direction (z axis), respectively. Therefore, combination of anterior portal and any one of lateral portal is sufficient to provide variation in all three directions w. r. t. original planned patient's position. A known shift of 0.5 cm, 1.0 cm and 1.5 cm were introduced in longitudinal (in and out), lateral (right and left) and vertical (up and down) directions, respectively, and EPID images were acquired for each shift at a particular SID. The measurements were repeated for same shift at varying SID at 140.0 cm, 149.9 cm, 159.9 cm and 179.9 cm. These portal images were matched manually on the console monitor as well as offline review on TPS [Fig. 2] and measured shift were recorded for each portal image. The expected shifts and observed shifts are given in Tables 1-3.
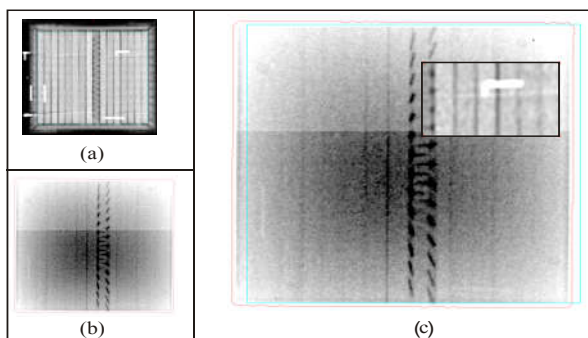
Fig. 2 (a) The anterior DRR image (b) The image acquired from EPID and (c) The blended image obtained during manual match of acquired image (shown in background) and DRR image(shown in inset)

RESULTS

Table 1 illustrates the expected and observed shifts obtained for different beam angles (gantry angles 0⁰, 90⁰ and 270⁰ for anterior, left lateral and right lateral portal images, respectively) in the longitudinal direction at varying SID. The maximum and minimum difference among all shifts in the inward and outward direction was found to be 3 mm and zero, respectively [Fig. 3(i)].

The maximum error obtained for 179.9 cm SID was 2 mm. There was no difference between the expected and observed values at imager distance 179.9 cm for inward shifts obtained in left lateral portal images and outward shifts obtained for right lateral portal images. The frequency of occurrence of maximum error of 3 mm was highest obtained for imager distance 149.9 cm. Table 2 provides the information of lateral shifts obtained from portal image at 0⁰ gantry angle (anterior portal image) and the difference between the expected and observed shift in the lateral directions (left and right lateral). The maximum difference between the expected and observed shift was found to be 3 mm and was obtained both for imager distance 140.0 and 159.9 cm [Fig. 3 (ii)]. The maximum error obtained were 2 mm both for imager distances 149.9 and 179.9 cm. Table 3 shows the error obtained in vertical direction for manually introduced shift. The maximum shifts between expected and observed values were found to be 3 mm and the frequency of occurrence is maximum for imager distance 179.9 cm both for lateral portal images. There is no difference between observed and expected values of shifts for images acquired from left lateral portals at 149.9 cm while maximum difference obtained from online correction were 2 mm for the right lateral portal images [Fig. 3(iii)]. The maximum difference obtained for imager distance 159.9 cm was 2 mm.

Table 1 The expected and observed (obs.) shifts in the longitudinal direction obtained from different portal image at different SID.

SID (cm)	Anterior portal image				Left lateral portal image				Right lateral Portal image			
	inward shift (cm)		outward shift (cm)		inward shift (cm)		outward shift (cm)		inward shift (cm)		outward shift (cm)	
	Expected	Obs.	Expected	Obs.	Expected	Obs.	Expected	Obs.	Expected	Obs.	Expected	Obs.
	-0.5	-0.7	0.5	0.4	-0.5	-0.7	0.5	0.5	-0.5	-0.3	0.5	0.6
140.0	-1.0	-1.1	1.0	0.9	-1.0	-1.1	1.0	0.9	-1.0	-1.1	1.0	1.0
	-1.5	-1.8	1.5	1.4	-1.5	-1.3	1.5	1.4	-1.5	-1.8	1.5	1.5
	-0.5	-0.5	0.5	0.4	-0.5	-0.5	0.5	0.4	-0.5	-0.3	0.5	0.8
149.9	-1.0	-1.3	1.0	0.8	-1.0	-0.9	1.0	0.7	-1.0	-1.0	1.0	1.1
	-1.5	-1.4	1.5	1.3	-1.5	-1.8	1.5	1.3	-1.5	-1.5	1.5	1.7
	-0.5	-0.6	0.5	0.5	-0.5	-0.4	0.5	0.4	-0.5	-0.4	0.5	0.7
159.9	-1.0	-1.2	1.0	1.0	-1.0	-1.0	1.0	0.8	-1.0	-1.0	1.0	1.0
	-1.5	-1.7	1.5	1.3	-1.5	-1.4	1.5	1.2	-1.5	-1.5	1.5	1.6
	-0.5	-0.6	0.5	0.5	-0.5	-0.5	0.5	0.4	-0.5	-0.6	0.5	0.5
179.9	-1.0	-1.2	1.0	0.9	-1.0	-1.0	1.0	0.8	-1.0	-1.1	1.0	1.0
	-1.5	-1.7	1.5	1.3	-1.5	-1.5	1.5	1.3	-1.5	-1.6	1.5	1.5

Table 2 The expected (exp.) and observed (obs.) lateral shifts obtained in the anterior portal image.

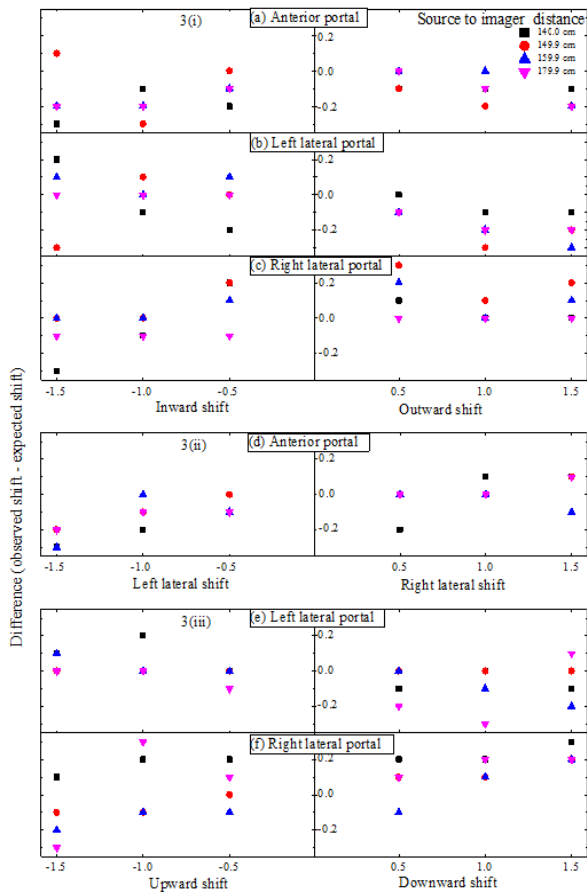| SID (cm)	Left lateral shift (cm)		Right lateral shift (cm)	
	expected	observed	expected	Observed
	-0.5	-0.6	0.5	0.3
140.0	-1.0	-1.2	1.0	1.1
	-1.5	-1.8	1.5	1.6
	-0.5	-0.5	0.5	0.5
149.9	-1.0	-1.1	1.0	1.0
	-1.5	-1.7	1.5	1.6
	-0.5	-0.6	0.5	0.5
159.9	-1.0	-1.0	1.0	1.0
	-1.5	-1.8	1.5	1.4
	-0.5	-0.6	0.5	0.5
179.9	-1.0	-1.1	1.0	1.0
	-1.5	-1.7	1.5	1.6

Fig. 3 The graphical representation shows the expected shift in longitudinal, lateral and vertical directions verses difference between the expected and observed shift at varying SID (all units are in cm).

orientations. Rowshanfarzad *et al.* [25] found that the sag in EPID was found to be 0.3 mm and 2.5 mm in cross-plane and in-plane direction. Although the large deviation was observed for in-plane as that of cross plane direction and the accepted criterion for non-stero tactic linac is 2 mm as per AAPM TG 142 report [26]. The on-board imaging of patients suffering from different types of tumors is done at different imager distances. This is because of limitation of imaging system, location of tumor and coverage of larger target volumes. For example, the patient suffering from cervix carcinoma and having anterior posterior separation more than 30 cm, the image cannot be acquired at 140 cm. This is due to more possibility of collision between imager and the treatment couch. Similarly for the same patient, it is difficult to acquire image in the lateral direction for same SID. The same problem was also observed for peripheral (non-centric) tumors. In cranio-spinal irradiation, brain was treated with lateral opposed isocentric fields with collimator rotation and isocentric table rotation and a single dorsal field is not sufficient to cover the whole spine for adult patients. In order to cover the whole spine, source to surface distance was increased as compared to the routine treating distances [27]. Therefore, the imaging was done by EPID for such patients at extended imager positions. These setups may require verification of, e.g., reproducibility of change in source to imager distance, sag in the gantry during rotation therapy, sag in the carriage mounted in the head of the Linac unit to accommodate the different accessory, e.g., MLC, blocks etc. In such setups, EPID plays very important role in terms of ease and less time consumption. The relation between expected and observed shift was well correlated and geometrical accuracy was maintained at all imager position.

Table 3 The expected and observed vertical shifts obtained in the lateral portal images at different SID.

SID (cm)	Left lateral portal image				Right lateral portal image			
	upward shift (cm)		downward shift (cm)		upward shift (cm)		downward shift (cm)	
	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed
140.0	-0.5	-0.5	0.5	0.4	-0.5	-0.3	0.5	0.7
	-1.0	-0.8	1.0	1.0	-1.0	-0.8	1.0	1.2
	-1.5	-1.4	1.5	1.4	-1.5	-1.4	1.5	1.8
149.9	-0.5	-0.5	0.5	0.5	-0.5	-0.5	0.5	0.6
	-1.0	-1.0	1.0	1.0	-1.0	-1.1	1.0	1.1
	-1.5	-1.5	1.5	1.5	-1.5	-1.6	1.5	1.7
159.9	-0.5	-0.5	0.5	0.5	-0.5	-0.6	0.5	0.4
	-1.0	-1.0	1.0	0.9	-1.0	-1.1	1.0	1.1
	-1.5	-1.4	1.5	1.3	-1.5	-1.7	1.5	1.7
179.9	-0.5	-0.6	0.5	0.3	-0.5	-0.4	0.5	0.6
	-1.0	-1.0	1.0	0.7	-1.0	-0.7	1.0	1.2
	-1.5	-1.5	1.5	1.6	-1.5	-1.8	1.5	1.7

DISCUSSION

In the present study, IMRT graticule phantom was used to develop QA program for retractable arm EPID. The phantom have no breathing motion, therefore the error between the image acquired by the EPID and reference (DRR) image is either due to inbuilt error within in the imaging system or personnel error while matching these two images or effect of EPID sag at different orientations w.r.t. phantom position. For sufficiently large difference between planned position and the treatment position, appropriate corrections have to be applied. The study was carried out to find the effect of sag in EPID due to gravity at extended imager distances and varying beam

The maximum error was obtained to be 3 mm and it occurs for almost all imager positions w.r.t. the beam direction. If the gravity sag is significant then it will show large variations for that particular imager orientation w.r.t radiation beam, i.e., right lateral and left lateral positions and extended imager position. The fine correlation between expected and observed error shows non-considerable effect of EPID sag due to gravity at the image acquisition.

CONCLUSION

The IMRT graticule phantom is a useful tool to check the geometrical accuracy and hence the QA of EPID. The method

used in this study is very effective to check the mechanical characteristic and consistency of the retractable arm EPID (Varian Oncology Ltd) and can be performed routinely for other supporting arm EPID. The effect of EPID sag due to gravity was not significant for detection of shift in the patient's position. The positional reproducibility of phantom with EPID (R-arm) was well maintained. Any slight variation can due to fluctuation in the position of EPID or personnel errors while matching the DRR and portal image obtained for a known shift at different SIDs. The close agreement between expected and measured shift at different distances and different orientations (gantry angles 0^0, 90^0 and 270^0) imply that EPID have proved effective tool for routine verification of patient setup during treatment in extended SID setups.

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