Impact Of Patient Position Verification Using MV-EPID Vs KV-CBCT Images in Linear Accelerator

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Abstract— In Radiotherapy, patient position verification is most important for accurate dose delivery. The imaging verification provide the good clinical outcome results for the patient. In this study, we compared two different imaging modalities such as EPID versus CBCT in linear accelerator

Index Terms- Electronic Portal Imaging Device, Cone Beam Computed Tomography, Linear Accelerator

I. INTRODUCTION

The imaging modality plays an important role in the radiation treatment of cancer patients. Patients who underwent image verification shows better clinical outcomes compare than patients treated without image verification [1]. Accurate radiation delivery to the target volume improves the tumour control probability and reduces the treatment related morbidity.

In some cases such as the prostate cancer where the organ distension of rectum and bladder affects the dose delivery to the target. For accurate dose delivery, daily image verification is effective method for this kind of treatment [2]. Bladder protocols, surface marking, immobilization devices are developed for reduce the set up errors during the treatment and delivers the accurate dose to the target.

In earlier days, two dimensional (2D) orthogonal port film radiographs at gantry angles zero degree (anterio posterior) and 90 or 270 degree (lateral) were used for patient set up verification in manual planning. The port films were taken before the first treatment and not verified during the course of treatment. It couldn't be useful during the course of treatment, because of lesser anatomical details in the port films [3,4].

The evolution of computed tomography (CT) in radiology is a boon for the imaging modalities. CT unit is equipped with X-ray tube and multi detectors using low energy kV X-rays to provide the better resolution compared to orthogonal port films [5].

Nowadays, linear accelerators (LINAC) incorporated with an imaging panel which provides digital orthogonal images using mega voltage (MV) energy such as 4MV or 6 MV energy. This imaging modality is known as electronic portal imaging device (EPID)[4]. MV EPID uses high energy X ray beams to produce images which are needed for analysing the bony structures in orthogonal views and also the software allows the contrast and brightness adjustment for the good quality image. In EPID, the bony landmarks serve as a surrogate indicator of the tumour and it has the limitation of soft tissue delineation. This issue was overcome by using the cone beam CT (CBCT) image verification.

The three dimensional (3D) image verification which initially was started with MV CBCT and now has moved to the kilo voltage CBCT (kV- CBCT) due to lesser exposure of radiation dose. The CBCT systems enable to provide the imaging in a single 360 degree rotation around the patient (arc). These images are reconstructed by back projection of hundreds of 2D images acquired using a large area of amorphous silicon detector. In many literature, treatment set up uncertainties discussed based on imaging modalities. This study focuses on the differences between 2D MV EPID and 3D kV CBCT images [5].

The aim of the present study is to compare set up variation between EPID versus CBCT imaging modalities for various techniques of different sites.

II. MATERIALS AND METHODS

Fifty patients who received radiation for various sites such as brain, head and neck, thorax, abdomen and pelvis from May 2021 to September 2021 were included in this study. All patients were immobilized by thermoplastic cast treated with radical radiation using various treatment techniques. The patients underwent both EPID and kV CBCT for initial three days during the treatment.

i) Patient imaging verification:
The imaging modalities of MV EPID and kV CBCT of Elekta Synergy used for patient set up image verification and imaging viewed through software called iView GT. The 4 MV X-ray energy is used for obtaining the images with the field size of 24 cm x 24 cm amorphous silicon detector panel in gantry angles of zero degree (AP) and 270 degree (LAT).

CBCT images were viewed in the software called X Ray Volume View (XVI). The X rays used with 100 kV to 120 kV with different mAs for different sites. The gantry angles for kV image acquisition are automated with certain fixed start and stop points.

The image was acquired using kV X-ray tube and the amorphous silicon panel which included the movement adjustments of the panel. The image acquired with kV CBCT was viewed by multiple display methods such as green purple, cut, localization only and reference only options. The image was matched through manual, bone (T+R), grey value (T+R) and grey value (T).

Once the verification was done, the variations were observed in X axis (lateral), Y axis (longitudinal) and Z axis (vertical) coordinates and documented. Corrections were applied based on the average of the values obtained on the initial three days

ii. Statistical software:
Descriptive statistics was done using Microsoft excel software. The statistical calculation was done by Wilcoxon signed rank test using statistical package for the social sciences (SPSS) software.

III. RESULTS

Table 1 shows patient distribution:

Patient characteristics	Distribution		
No of patients Male Female	50(100%) 31(62%) 19(38%)		
Treatment site	Male	Female	Total
Head and neck	11	9	20
Pelvis	5	4	9
Thorax	11	5	16
Extremities	1	1	2
Brain	3	-	3
Total	31	19	50

Table 1 explains the patient characteristics. Among 50 patients, 31 male patients and 19 female patients were taken for this study. For treatment wise, twenty patients were treated in head and neck cancer, nine patients were treated in pelvis, sixteen patients were treated in thorax, two patients were treated in extremities and three patients were treated in brain respectively.

Table 2: Position variation in X, Y, Z directions in EPID and CBCT

Day	MV EPID Median (Range) (cm)			kV CBCT Median (Range) (cm)			P value		
	X	Y	Z	X	Y	Z	X	Y	Z
Day 1	0.25 [-1.0 -2.13]	1.0 [-2.6-3.0]	0.0 [-1.5-1.1]	1.2 [-0.7-2.9]	0.7 [-2.2-3.1]	-1.0 [-3.3-1.5]	0.04	0.01	0.006
Day 2	0.0 [-0.6-1.6]	0.5 [-2.5-2.6]	0.0 [-1.1-1.0]	0.7 [-0.7-4.0]	1.0 [-3.1-3.5]	0.0 [-2.0-0.8]			
Day 3	1.0 [-0.6-2.1]	1.75 [-2.0-3.0]	0.25 [-2.0-3.0]	1.3 [-1.1-3.0]	2 [-1.5-3.0]	-0.7 [-2.9-2]			

Range is mentioned from negative integer to positive integer

X- Lateral

Y-Longitudinal

Z- Vertical

Table 3: EPID bony landmarks for AP and lateral image:

Treatment site	Reference bony landmarks (AP image)	Reference bony landmarks (Lateral image)
Head and neck	Internal and external mandible profiles, skull base and cervical vertebral bodies (C2-C4).	External mandible profile, nasal septum, maxillary sinus and the spinous process of one of lower cervical vertebrae.
Brain	Nasal septum, maxillary sinus, base of posterior skull, vertebras.	Base of the skull, body and spine of C2 vertebra.
Pelvic and prostate	Coccyx bone, L5-S1, pubic symphysis, gold fiducial markers (in case with prostate cancer).	Pubic symphysis, obturator foramen, iliac crest, gold fiducial markers (in case with prostate cancer).

Table 2 explains about the variation between the EPID vs CBCT imaging techniques in x axis, y axis and z axis for three consecutive days. We observed the values ranges from negative integer to positive integer for all directions. We found little higher values in CBCT compared to EPID and statistical significance {p value= 0.047(x-axis), 0.018 (y-axis) and 0.006(z-axis)} in all axes. Figure 1 and 2 shows the EPID image of head and neck cancer and CBCT image of thorax cancer.

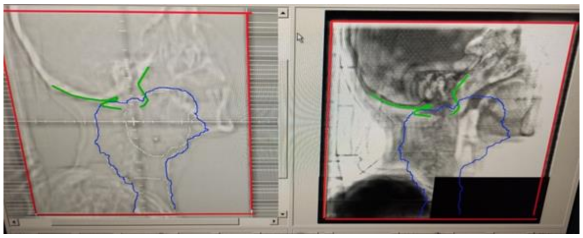

Figure 1 shows the EPID image of Head and neck cancer

Figure 2 shows the CBCT image of thorax region

IV. DISCUSSION

Imaging modalities serve us accurate dose delivery to the patient and also reduce the positional errors in daily set up. EPID and CBCT images are widely used for the patient position verification. Both imaging modalities has their own advantage to patient set up errors. Many literature explained and compared between EPID and CBCT images.

Martins L et al compared between the kV EPID versus kV CBCT images in their study for patient image verification. Sixteen oesophagus patients were taken for this study and observed statistical significant in X axis (p = 0.003). They concluded in their study that kV CBCT images were better choice compared to kV EPID. We found statistical significant difference in all directions when compared for all tumour sites [6].

Zaghloul M.S. et al, compared in their study, the patient position verification using MV EPID and MV CBCT in children for initial three days.() Seventy two patients were taken for this study. Among them, 18 patients were under anaesthesia in the whole treatment. Bony templates were matched with digitally reconstructed radiograph (DRR) of the planning CT with EPID portal images. MV CBCT were done using Optivue flat panel and the patient anatomy was superimposed with registration for bone, air and soft tissue of planning CT. In their study, the systematic and random errors were observed. In Head & Neck cancers the errors were significant in lateral (X-axis) and vertical directions (Z-axis) [p=0.027, 0.003], whereas other cancers it was observed in vertical direction (Z-axis)[p=0.031] only. Similarly, we observed systematic and random errors in our study and found statistical significant difference in all directions [7].

Nunen Van. A. et al, they have done comparison of 50 patients of oesophagus cancer using kV CBCT and MV EPID similar to our study. They found kV CBCT based position verification produces less set up error when compared with the EPID verification [8].

In our study, we observed that the comparison of degree of variation between EPID and kV CBCT. EPID gives us the bony landmarks anatomical clearance, but it couldn't visualize the soft tissue clearly. Table 3 explains about the reference landmarks for AP and lateral images for EPID verification for different sites in our study [9].

In kV CBCT, we obtain a 3D image which helps us tracking the internal organs. This is also useful in malignancies of the pelvis where bladder protocol is given as a part of the treatment. Bowel dose can be minimized by giving an adequate bladder protocol and tracking the same on kV CBCT images. Hence, with bladder protocol CBCT is preferred to check the bladder volume and also to track the motion of the bladder. In case of thorax and abdomen cases, EPID system is providing only the vertebra and spine and clavicle bone match but in most cases when the patient is obese those kind of bony landmarks are not clearly visible hence challenging to match. Because region of interest may be sometimes near to the clavicle and sometimes close to the diaphragm region.

But in case of CBCT we are able to clearly identify the PTV volume and also the nearby structures which will lead to the justification of our verification with proper imaging modality. In cases of oesophagus patients it is easy to track with the aorta and vertebral bones, along with the PTV margin for oesophagus. In patients those are getting treatment in head region we match the cranial bone and cervical vertebra in EPID but in case of CBCT we can directly identify the point of interest. We found CBCT values are little superior compare to EPID values, because of more accurate soft tissue image delineation and observed more set up errors and correct the errors before the patient treatment.

CONCLUSION

CBCT is more accurate compared to EPID image for patient position verification. This study has shown a significant difference between kV CBCT and MV EPID in all directions. EPID has also shown reliable results for patient position verification and can be used as an alternative to CBCT when CBCT is non-available in the centre.

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REFERENCES

[1] Kanakavelu Samuel J J , Determination of patient set-up error and optimal treatment margin for intensity modulated radiotherapy using image guidance system, JBUON 2016; 21(2): 505-511.

[2] Dzierma Y, Beyhs M ,Palm J , Niewald M , Bell K, Nuesken F, Licht N, Rübe C, Set-up errors and planning margins in planar and CBCT image-guided radiotherapy using three different imaging systems: A clinical study for prostate and head-and-neck cancer. Physica Medica (2015)

[3] Jaffray D .A , Drake D.G , Moreau.M, Martinez A.A. ,Wong J W,A Radiographic and tomographic imaging system integrated into a medical linear accelerator for localization of bone and soft-tissue targets, Int. J. Radiation Oncology Biol. Phys., Vol. 45, No. 3, pp. 773–789.

[4] Mahdavi S.R, Gharehbagh E. J, Mofid B, Jafari A.H, Nikoofar A.R. Accuracy of the dose delivery in prostate cancer patients-using an electronic portal imaging device (EPID)International Journal of Radiation Research, 2017, Volume 15, No 1.

[5] Jaffraya D.A,Siewerdsen J.H, Cone-beam computed tomography with a flat-panel imager: Initial performance characterization .Med. Phys.2000

[6] Martins L, Couto J.G. , Barbosab B , Use of planar kV vs. CBCT in evaluation of setup errors in oesophagus carcinoma radiotherapy, Report of Practical Oncology and Radiotherapy,2016;57-62

[7] Zaghloul M.S, Mousa A.G, Eldebawy E, Attalla, Shafik H, Ezzat.S Comparison of Electronic Portal Imaging and Cone Beam Computed Tomography for Position Verification in Children. Clinical Oncology; 2010; 850-861.

[8] Nunen A.V., Sangen M.J.C., Boxtel M.V, Haaren V. Cone-Beam CT-based position verification for oesophageal cancer: Evaluation of registration methods and anatomical changes during radiotherapy. Technical Innovations & patient in Radiation oncology; 2017; 30-36.

[9] Molana S, Arbabi F, Sanei M, Hashemi E, Tajvidi M, Rostami A, et al. Evaluation of Patient setup Accuracy and Determination of Optimal Setup Margin for External Beam Radiation therapy using Electronic Portal Imaging Device. Cancer therapy & oncology 2018;2:1-8.