

Impact of Imaging Modality in assessing Patient setup for Different sites in Radiotherapy

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ABSTRACT

Aim: The purpose of the study is to find the imaging modality that is best suitable for patient setup verification in external beam radiotherapy for various sites.

Materials and Methods: For the study, 10 patients were selected retrospectively for each of brain, head and neck, thorax, abdomen and pelvis. For all patients both megavoltage (MV) and kilovoltage (kV) orthogonal images were acquired as a part of setup verification. The corrections for setup (X, Y, Z directions) were recorded for each patient for each imaging modality. Also, the time taken for image verification was noted for both imaging modalities.

Results: The cumulative mean couch applied shifts for all the patients for MV imaging modality was 2.8 mm in lateral, 2.6 mm in vertical and 3.1 mm in longitudinal direction. The cumulative mean couch applied shifts for all patients for kV imaging modality was 2.4 mm in lateral, 2.3 mm in vertical and 2.8 mm in longitudinal direction.

Conclusion: The study showed that image verification in kV imaging is faster and more accurate as compared to MV imaging because of superior image quality. However, MV can still be used by double exposure method. MV image system requires further research in image processing methods especially in thorax and abdomen cases.

Keywords: Setup error, kV image, MV image, image guidance

INTRODUCTION

External beam radiotherapy involves use of ionizing radiation to treat cancer. The use of telecobalt in external beam radiotherapy is decreasing with the emergence of linear accelerators. High energy linear accelerators offer better skin sparing than telecobalt machines.

Now a days, high energy linear accelerators that are capable of producing X-rays and electrons of different energies are available. There have been several advancements in radiotherapy since the invention of Multi leaf collimators. MLC was the game changer in radiotherapy. MLCs led to the wide spread use of three dimensional conformal radiotherapy (3DCRT). 3DCRT uses multiple beam angles to deliver conformal dose distribution, thereby reducing dose to critical structures. 3DCRT are widely used in the treatment of prostate, bladder, oesophagus and H&N cancers. 3DCRT is based

on forward planning where the treatment delivery parameters are optimized manually to achieve a desired dose distribution and the quality of the plan is highly planner dependant.

With the introduction of Intensity modulated Radiation therapy (IMRT), dose to Organ at risks (OARs) were significantly less and dose escalation to tumors was viable. This also led to simultaneous integrated boost treatments which are especially useful in head and neck cancers. IMRT paints the dose on to the tumor precisely with the help of MLCs. It guides the beams of radiation to the tumor from many different angles. At each of these angles, the intensity of the radiation is modulated and the shape of the beam is changed to match the shape of the tumor. These adjustments enable the prescribed amount of dose to be delivered to each part of the tumor at the same time minimizing exposure to the surrounding healthy tissue.^[1]

With the increase in the use of modern treatment delivery techniques like IMRT, patient setup verification plays a vital role in achieving the radiotherapy treatment goals. The generated dose distribution has to be anatomically matched with the patient before treatment delivery. IMRT plans generate non-uniform fluences using inverse planning algorithm. This motivates image guidance in radiotherapy treatment especially before delivery. At present, image guidance has become a part and parcel of radiotherapy treatment.

All the vendors of linear accelerators offer imaging systems isocentrically mounted to the gantry of the machine. Linear accelerators have two different imaging modalities that allow for images of the patient to be made while the patient is on the linear accelerator. The most common imaging system available with the linear accelerators is mega voltage (MV) imaging system. MV imaging uses 6MV X rays and electronic portal imaging device (EPID) to acquire the image of patient for treatment positioning verification.

It produces an image of the patient by the use of the 6 MV beam of radiation that the linear accelerator emits to treat the tumour. Earlier liquid system based detectors lacked resolution. However, new detectors based on amorphous silicon offer better resolution (aS1000). Improvement in technology led to introduction of orthogonal kV imaging system mounted isocentrically on the machine. It uses the same diagnostic range of kilo voltage (kV) X rays to produce images.

The images from the KV Imaging system are clearer. Also, with the kV imaging system we can obtain volume images by cone beam computed tomography (called in short as CBCT). With this we can get 3-dimensional images of the patient in treatment position.^[2,3] Accurate and good setup of patients is important in radiotherapy because of the closeness of the treatment volume to critical structures. When advanced radiotherapy like IMRT and VMAT is used, improper setup may lead to over dosage of critical organs close to planning target volumes.^[4-9]

MV imaging systems comes as part of the standard linear accelerator machine.^[10] Hence it is cheap. Although orthogonal kV images produce good quality of images, it is very costly compared with the MV imaging system. Not many hospitals in our country can afford costly machines.

In this paper we compare both the imaging modalities in the aspect of quality and convenience and try to find out the best suited imaging modality for different sites.

MATERIALS AND METHODS

10 patients for different sites including brain, head and neck (H&N), thorax, abdomen and pelvis were retrospectively selected. The Varian True Beam machine

was used for the study. The machine has both MV and kV imaging systems available. MV imaging system consists of aS1000 panel (detector) as the image generation system.

The detector is taken out remotely to a predefined image acquisition position. This uses the 6 MV linac beam as source for the image generation. Single exposure and double exposure methods of image acquisition are available. Double exposure method is used to obtain enhanced images. Double exposure is better in bulky patients. This system is robust and the image acquisition can be made faster with the single exposure technique. Single exposure technique is used in sites where separation is less. Also single exposure reduces the dose to the body as compared with double exposure.

The kV imaging system of the machine is orthogonally mounted to the MV X-ray beam system, where both the source and detector is robotically taken in and out from retracted position. This is an add-on system as compared to the MV imaging system. KV images were obtained with preset values already present in the On-board Imager (OBI) system. The preset kV and mAs values for each site were not changed manually to acquire images. The Varian MV and kV imaging systems are very robust and has been tested in literature.^[2]

The kV and MV images were taken on the same day before the treatment delivery. Imaging was done on alternate days and not daily. Images were not acquired on a daily basis due to workload on the treatment machine. Couch shifts in X (lateral), Y (vertical) and Z (longitudinal) directions were corrected before treatment delivery and noted.

The mean couch shifts in all directions for all sites for all patients were noted for both the imaging modalities. Values of couch shifts are available in offline review platform of eclipse software (version 13.1). The mean time taken to acquire an orthogonal image set for each image modality is also noted and also noted.

RESULTS

The mean couch shift correction applied for each patient for different sites in each imaging modality is presented as figures. Figures 1 & 2 represent the mean shift for brain cases in MV and kV imaging respectively. Figures 3 & 4 represent the mean shift for head and neck cases in MV and kV imaging respectively. Figures 5 & 6 represent the mean shift for thorax cases in MV and kV imaging respectively. Figures 7 & 8 represent the mean shift for abdomen cases in MV and kV imaging respectively. Figures 9 & 10 represent the mean shift for pelvis cases in MV and kV imaging respectively.

The cumulative mean couch shifts for all patients for each

particular site for both imaging modalities was also found out and tabulated in table 1. Table 2 shows total mean time taken for image acquisition and total mean time taken for image interpretation and analysis for all sites.

DISCUSSION

Two different techniques that are available commercially for pre-treatment patient set-up verification have been used in this study. MV imaging is compared with newly available kV imaging to determine the suitability of imaging modality for different sites. For brain case, there was the least difference between both the imaging

Table 1: Cumulative mean couch shifts for all patients

Site	Cumulative Mean shift for MV Imaging (mm ± SD)			Cumulative Mean shift for kV Imaging (mm ± SD)		
	X	Y	Z	X	Y	Z
Brain	2.2±1.8	1.6±1.6	2.3±1.8	2.0±0.9	1.4±1.3	2.0±1.4
H&N	2.5±1.5	2.7±1.4	2.7±1.2	2.2±1.1	2.4±0.8	2.4±1.0
Thorax	2.9±1.0	2.3±0.8	2.7±0.9	2.8±0.6	2.1±0.6	2.5±0.7
Abdomen	3.0±1.2	3.0±1.1	3.3±1.5	2.4±1.1	2.6±0.8	2.9±1.3
Pelvis	3.1±1.0	3.6±1.1	4.6±1.0	2.6±0.8	3.6±0.8	4.0±0.8

Table 2: Cumulative average imaging time for all patients

Site	Time for MV Imaging (secs)		Time for kV Imaging (secs)	
	Acquisition only	Analysis and acquisition	Acquisition only	Analysis and acquisition
Brain	80±10	130±20	40±10	80±15
H&N	80±10	150±20	40±10	80±15
Thorax	90±10	185±25	40±10	90±20
Abdomen	90±10	190±25	40±10	90±20
Pelvis	85±10	150±25	40±10	80±20

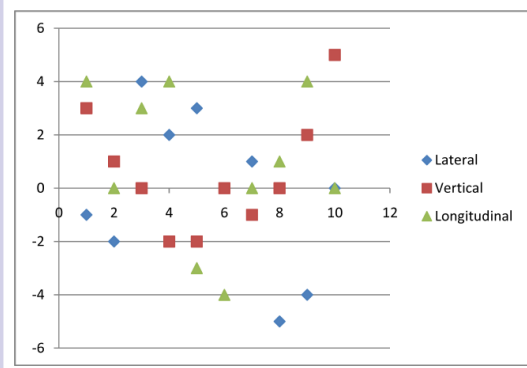


Figure 1 : MV imaging mean couch shifts for Brain

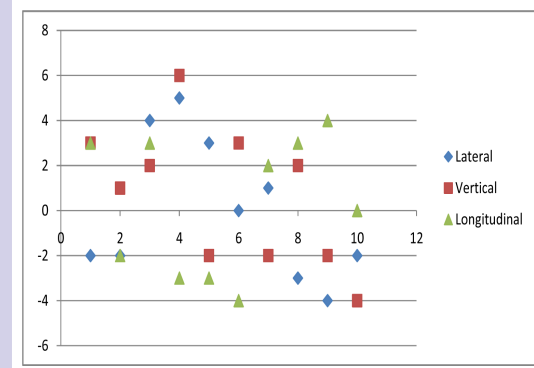


Figure 3 : MV imaging mean couch shifts for head and neck

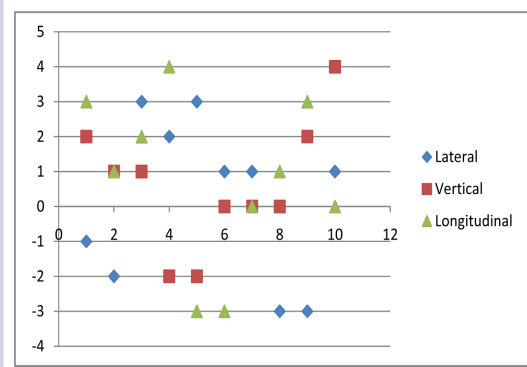


Figure 2 : kV imaging mean couch shifts for Brain

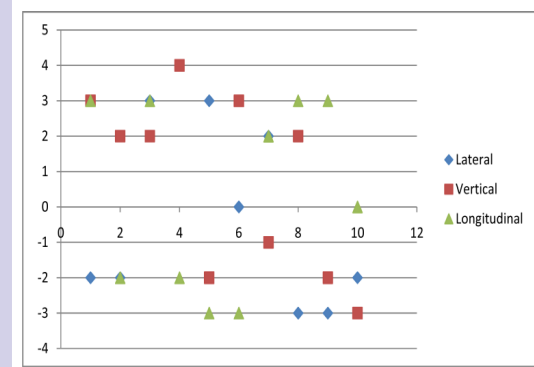


Figure 4 : kV imaging mean couch shifts for head and neck

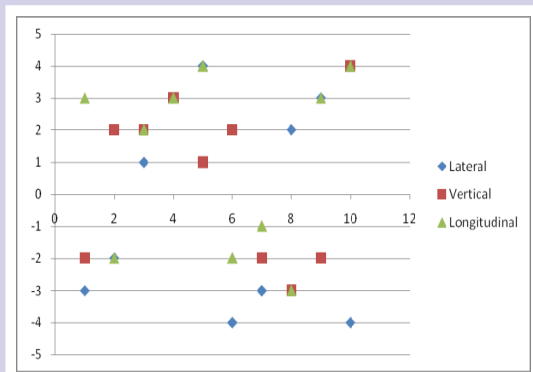


Figure 5 : MV imaging mean couch shifts for thorax

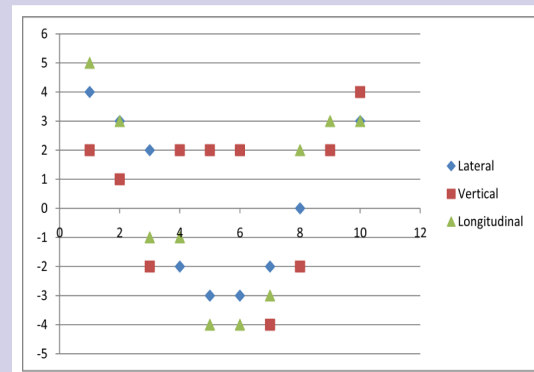


Figure 8 : kV imaging mean couch shifts for abdomen

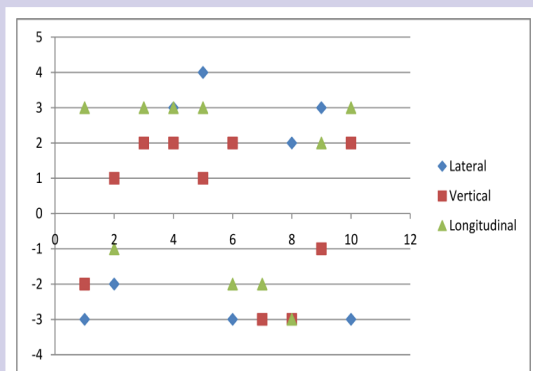


Figure 6 : kV imaging mean couch shifts for thorax

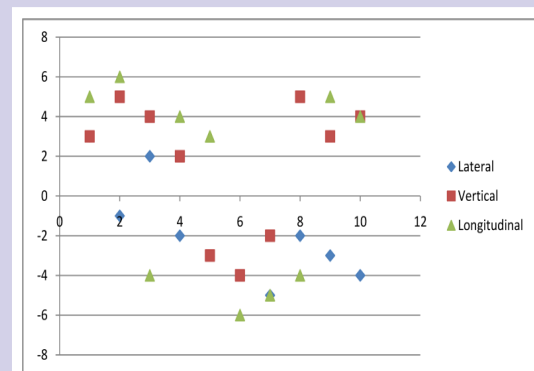


Figure 9 : MV imaging mean couch shifts for pelvis

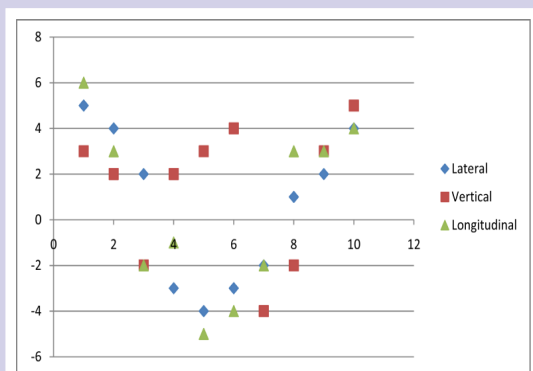


Figure 7 : MV imaging mean couch shifts for abdomen

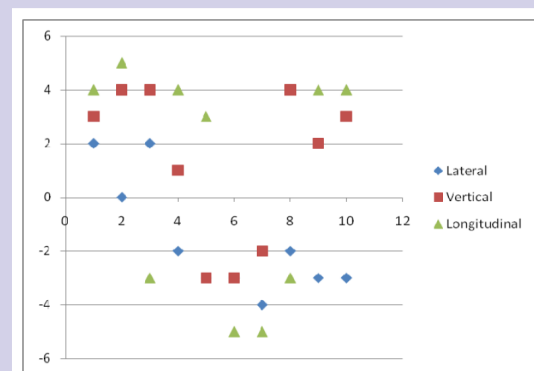


Figure 10 : kV imaging mean couch shifts for pelvis

modalities whereas for pelvis and abdomen cases the difference was higher in MV imaging method than kV imaging method. This is because of good quality of kV imaging in lateral images as compared to MV images.

The anterior images in both the modalities are more or less the same except for thorax and abdomen sites. For

all the sites it was observed that the kV images were better than the MV images for bony matching. This is because of the kV images produced are based on the principle of photo electric effect and hence they are better for bony matching.

MV imaging is better than kV imaging if bony matching

is "not" the criteria. Carina can be visualized in MV imaging in thorax cases which can be utilized for patient setup. In kV imaging carina cannot be seen. This is because MV imaging is based on Compton effect principle and all the tissues interact in the same way to radiation and hence soft tissue contrast is good in MV imaging. The average time taken for kV imaging is slightly less compared to the MV imaging. This is caused due to "double-exposure" technique employed in MV image system.

Thus, the average time including the image processing and analysis is further higher. It is inferred that the image interpretation is quite good and clear in the case of kV imaging due to superior contrast of acquired images. Although current MV imaging systems employ 'image enhancer' and various pre-defined contrast windows, they fail in producing good contrast images comparable to kV imaging system. This difference is more observed in thorax and abdomen sites, especially in lateral images, where the bony landmarks are difficult to identify. Thus it takes longer duration in image assessment of MV images. Also, Inter-observer variability is more in accessing MV image than kV image sets.

In brain, H&N and pelvic sites inter-observer variability does not make any big difference and hence MV imaging in these sites are much more dependable as kilo voltage imaging. Inter-observer variability is very less as both imaging system gives respectable quality images.

In thorax sites, especially in lung tumors MV images are greatly helpful in identifying gross tumor itself. But this is only a qualitative evaluation and cannot quantify the image verification. Else, kV imaging is more dependable in thorax and abdomen sites. Pelvis imaging is quite good for both the type of image modality as bony landmarks are clearly visible. Furthermore, there is no consensus still on which imaging modality should be preferred for setup verification.

The aim of setup verification is have reliable and accurate patient setup to prevent irradiation of critical structures. Usually anterior images in MV imaging are more or less comparable in brain, head and neck and pelvis. Combination of MV-kV imaging can be used in busy centers to save time. For thorax and abdomen, if kV images are available then it is preferable. If not available then double exposure method in MV imaging is preferable. It is inferred that the pelvis and abdomen sites require careful and slightly higher target margins when compared to other three sites. This is because of bulkiness of the patients in the lower parts of the body.

The data collected in the study can further be used to determine planning target margins and a robust site-specific margin protocol could be framed. But, at present

the determination of PTV margins for different sites is not carried out currently since more patient data is awaited.

CONCLUSION

This study has showed that image verification in kV imaging is faster and more accurate as compared to MV imaging because of superior image quality. However, MV imaging is more or less comparable to kV imaging in brain, head and neck and pelvis sites. In thorax and abdomen cases MV imaging can still be used by double exposure method. Single exposure method in MV imaging is also dependable to reduce image acquisition time. MV image system requires further research in image processing methods especially in thorax and abdomen cases.

CONFLICT OF INTEREST :

The authors declared no conflict of interest

FUNDING :None

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