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Editorial

Do we need to worry about imaging dose in IGRT?

Radiation therapy for the treatment of cancer has come a long way over the past 20 years. The techniques for delivering external beam radiation to tumor sites have improved dramatically with the introduction of Intensity Modulated Radiation Therapy (IMRT), Volumetric Modulated Arc Therapy (VMAT), etc. These advancements result in higher doses of radiation delivered more accurately to the tumor with the goals of better tumor control, higher survival rates, and fewer side effects. These techniques facilitate treatment of volumes with tight margins and hence the treatment outcome heavily relied on the patient setup accuracy and real-time information on the patient movement during treatment.

Image-guided radiotherapy (IGRT) is the new paradigm for external-beam treatment delivery, which facilitate constant monitoring of geographical coverage/miss of the target volume during fractionated Radiation Therapy. IGRT employs an on-board imager in conjunction with a linear accelerator to provide a better method of delivering more accurate and precise radiation treatments. IGRT also makes use of many imaging modalities ranging from portal imaging to fluoroscopy to megavoltage cone-beam CT and following regimens as simple as a single setup image or as complex as intra-fraction tumor tracking. For each patient undergoing radiation therapy, some form of image guidance is used during treatment. Depending on the area to be treated, normal organ motion may require daily image guidance, as is the case when treating the prostate, or more frequent imaging to guide radiation to fast moving organs, such as the lungs.

All radiographic guidance techniques can give a significant radiation dose to the patient. IGRT adds the imaging dose to an already high level of therapeutic radiation. The imaging dose received as part of a radiotherapy treatment has long been regarded as negligible and thus has been quantified in a fairly loose manner. The introduction of more intensive imaging procedures for IGRT now obligates the clinician to evaluate therapeutic and imaging doses in a more balanced manner. Numbers of imaging technologies have evolved over the year involving X-ray, ultrasound, or optical imaging to direct the delivery of radiation during radiation therapy treatment. Wherever feasible, it is worthwhile to adapt non-ionizing radiation imaging procedures in order to reduce the effect of concomitant dose arising during IGRT procedures. The scientific paper titled "The management of imaging dose during image-guided radiotherapy: Report of the AAPM Task Group 75" (https://www.aapm.org/pubs/reports/RPT_95.pdf) enumerates the details of imaging dose that are to be considered while Radiotherapy. The effective management of radiological imaging should be in the spirit of ALARA thereby to keep both dose and integral dose to a minimum level.

Sowmyanarayanan

Manuscript for the next issue of Medical Physics Bulletin may be sent by 30th June 2016
Website: www.ampi-k.org

Dosimetric evaluation of Amorphous Silicon Electronic Portal Imaging Device for verification of IMRT/VMAT plan

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Introduction

Electronic Portal Imaging Device (EPID) has become an important component in modern Radiotherapy using medical linear accelerators. Previously, EPIDs were used, primarily for patient position verification. More recently EPIDS have been employed for dosimetric verification purpose[1,2,3]. The use of EPID is based on the conversion of the EPID signal into dose[4]. The evaluation of the dosimetric properties of EPID is important, if EPIDs are to be used for dosimetric purposes[1, 2, 3]. The dosimetric properties of EPID and their applicability for dynamic IMRT/VMAT plan verification are therefore of current interest.

Materials and Methods

EPID studied in this work is aS1000 mounted with a retractable arm on a Clinic 2300 CD (Varian Medical System, USA) capable of delivering IMRT/VMAT with photon energies 6MV & 15 MV. This indirect type of imager consists of 1mm copper metal plate as buildup, a l34mg/cm^2 Gd_2O_2S:Tb as scintillating phosphor of thickness 0.34mm and a 30×40cm^2 (768×1024 pixel) a-Si array making the pixel resolution of 0.39mm×0.39mm. The imager has been calibrated according to vendor recommendation[4]. The calibration is performed such that 100 MU delivered with a 10×10cm^2 at isocenter will readout as 1 CU (Calibrated Unit), roughly corresponds to 1Gy[4].

Dosimetry Properties:

Dose Response: Response with dose was measured for radiation field with varying amount of MUs. The measurements were done for both 6MV & 15MV. The field size was 10x10 cm^2 centered at central axis. The imager was positioned at SDD =100cm.

Dose rate dependence: The pixel values should be a function of dose only, not on dose rate & should be able to accurately measure the dose even at high dose rates without being saturated[1, 2]. The dependence on dose rate was investigated by changing the dose rate setting (100 – 600 MU/min) of the linac while keeping the imager at a constant SDD of 100cm, 100 MU was delivered for the field size of 10x10 cm^2.

Field size response: The field size response of the EPID was compared to the ion chamber measurement. The detector was positioned at 100cm from the source and the field size defined by collimator jaw was varied from 2×2cm^2 to 28×28cm^2. Both sets of measurements were normalized to 10x10cm^2.

Response with leaf speed: It is important to ensure that the EPID accurately records the rapid changes in dose rate to a pixel that occur during dMLC radiation delivery[1]. Sliding window deliveries were performed with an equal 100 MU & varying leaf gap (2mm - 20mm) between the two banks of MLC leaves for a 10x10 cm^2 field.

Memory effect (Ghosting): Ghosting is considered as fundamental property of amorphous silicon EPIDs[1,2,5]. The imager at SDD=140cm was first irradiated with a small (10x10cm^2) field, after that with a large (20x20 cm^2) field and after that with another 20x20 cm^2 field. Each large field is delivered as soon as possible after the previous field. The acquired image of the two large fields was compared. This method was repeated for 3 series of measurement. In the first, (series a) 500 MU was delivered to the small field and 10 MU was delivered to each of the large fields. In the second, (series b) 50 MU was delivered to the small fields and 10 MU was delivered to each of the large fields. In the third, (series b), 50 MU was delivered to each field.

IMRT/VMAT plan Verification: The gamma evaluation (3% dose difference & 3mm DTA criteria) of measured dose against TPS calculated dose image with PDC algorithm were performed for standard MLC test pattern, simulating complex dynamic treatment (X-wedge, Y-wedge, Pyramid, Complex fields), 10 dynamic IMRT clinical cases with total 70 split fields and 10 VMAT clinical cases. The verification plan is delivered to the imager in air i.e., without a phantom and no additional buildup.

Results & Discussion

Dose Response: The EPID was found to respond linearly (linear regression coefficient r^2=1) with increasing MUs as shown in figure 1. But as illustrated in figure 2 under- response has been observed (CU/MU ratio should be constant) for both the energies below 20 MU. Maximum deviation was around 25% & 20% for 6MV & 15MV respectively at 2 MU. This under response or nonlinear response at low MUs may be due to frames acquired within the first few seconds of irradiation miss doses[1, 5]. So, from the above result it is cautioned to use the EPID for dosimetry at low MUs.

Dose Rate Dependency: No sign of saturation effect has been observed. Maximum deviation was found 0.66% & 0.42% for 6MV & 15MV respectively at dose rate of 400 MU/min. Variation shows only small differences (i.e., statistically insignificant) without any apparent trend for both energies. This is not surprising, since the EPID is calibrated separately for each dose rate. Our result was different in contrast to the other literature, which shows decreasing response with increasing dose rate. Therefore, the use of single dose rate calibration curve could not yield completely accurate result.

Response with leaf speed: Figure 4 illustrates the EPID signal linearity (Linear regression coefficient, r^2 =0.995) with leaf speed for 6 MV photon beam. It demonstrates that the EPID can record rapid temporal changes in dose rate occur during IMRT/VMAT deliveries through dMLC[1].

Field Size Dependency: Systematic increase was observed with increasing field size for both energies. Under-response for small fields and over-response for the bigger field ranges was observed for both energies with respect to ion chamber measurement. The maximum difference in field size response between EPID and ion chamber was 5.4% & 2.8% for 2×2 cm^2 and 7.5% & 7.6% for 28×28 cm^2 for 6 MV & 15 MV respectively. This could be due to increase in scatter radiation with increasing field size[1,2]. Since the scatter has low energy component, its effect on the EPID's phosphor response is enhanced compared to ion chamber due to presence of high atomic number components in the phosphor.

Memory effect: The memory effect i.e., increase in the signal due to ghosting, is higher in measurement series a (1.2%) and in series b & c (considered as clinically relevant case) is around 0.41% & 0.27%. This must be considered as negligible for the application of pretreatment dosimetric verification[2,5]. These result also indicates that amount of ghosting is dependent on the number of MUs of previous irradiation, but not the number of MUs to the image where ghosting was observed.

IMRT/VMAT plan Verification: Gamma analysis for all the plans of standard MLC test patterns were passed for 2% - 2mm criteria. Similarly, out of 70 fields of 10 IMRT cases 87.1% were passed for 3%-3mm and 100% of analyzed fields were passed for 4%-4mm gamma criteria. The analyzed 10 VMAT clinical cases shows average gamma of less than 1 ($\gamma \leq 1$) at 3%-3mm gamma criteria.

In addition to the tests discussed above EPID signal response with gantry angles (Gravity effect) has been evaluated and found maximum deviation of 0.41% & 0.15% for 6MV & 15MV respectively. Short term reproducibility over time (30 Days) also has been checked and found to be within 0.5% for both energies. The variation obtained was considered as negligible.

Uncertainties: The uncertainties associated with these measurements were scatter from arm and lack of buildup. The lack of build-up is expected not to pose a problem since the thickness of intrinsic build-up was fixed, leading to reproducible result.

Conclusion

Several dosimetric properties of amorphous silicon EPID were assessed. The EPID has linear dose response for static as well as dynamic delivery, independent of dose rate & gantry angle and the signal is highly reproducible. Memory effect due to ghosting in clinically relevant scenario has been observed minimal. Limitations of the EPID system were identified including a field size dependent response and under response at lower MUs (< 20MU). The agreement between acquired and predicated image were found to be in good agreement for all the IMRT/VMAT plans. The result presented in this study indicates that EPID is a suitable dosimeter to verify the delivery of dynamic treatment fields (IMRT/VMAT).

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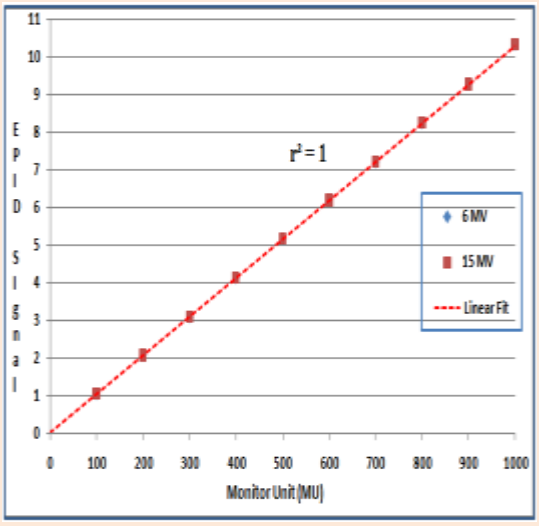

Fig 1: EPID signal (CU) response with varying MUs

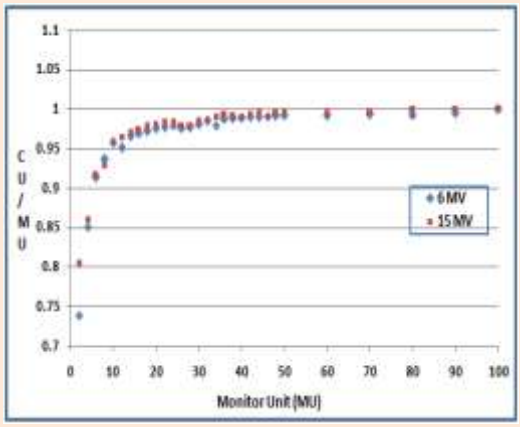

Fig 2: Ratio of EPID signal (CU) to the MUs plotted as a function of delivered MUs

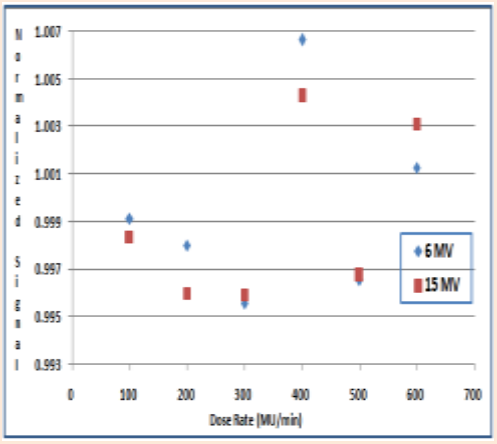

Fig 3: EPID signal (CU) response with dose rate

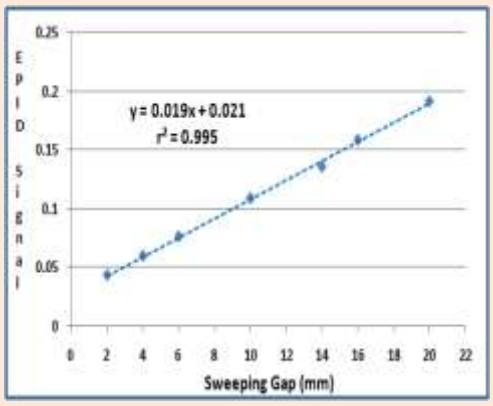

Fig 4: EPID signal (CU) response with leaf speed

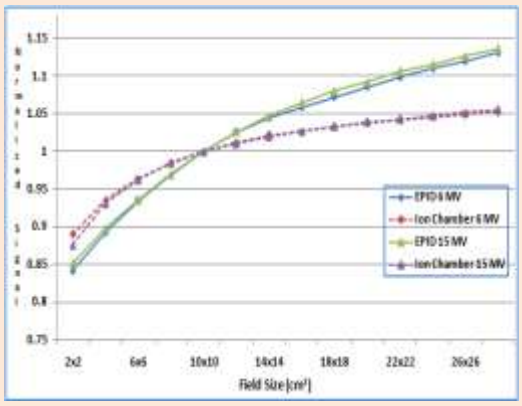

Fig 5: EPID signal (CU) and Ion chamber signal with field size normalized to the 10×10 cm^2

Karnataka Chapter – AMPI events

CME on Recent Trends in Volumetric Arc Therapy

Scientific event took place at Manipal Hospital, Bangalore with Karnataka Chapter-AMPI

1st August 2015


More than 100 participants were attended the meeting, comprising Radiation Oncologists, Radiologists, Physicists, Technologists, PG students, application specialists from companies.

National Symposium on Optically Stimulated Luminescence Dosimetry in Advanced Radiotherapy Practice

Scientific event took place at Kidwai Memorial Institute of Oncology, Bangalore with Karnataka Chapter-AMPI

26th September 2015


More than 200 participants were attended the meeting, comprising Radiation Oncologists, Radiologists, Physicists, Technologists, PG students, application specialists from companies.

Karnataka Chapter – AMPI events…contd…

Symposium on 'Recent trends in Medical Physics & Radiation Protection
International Day of Medical Physics-2015

Scientific event took place at Kastuba Medical College & Hospital, Mangalore with Karnataka Chapter AMPI

7th November 2015

The symposium was conducted with 7 invited talks and 15 oral presentations. ***Mr. Henry Finlay Godson*** *received the* ***first Curie award*** *for the* ***best oral presentation****. About 150* participants were attended the meeting.

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Evaluation of machine specific and plan specific quality assurance of Intensity Modulated Radiation Therapy

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Introduction

Intensity-modulated radiation therapy (IMRT) represents one of the most significant technical advances in radiation therapy since the advent of the medical linear accelerator. IMRT is performed by inverse treatment planning which improves the dose distributions compared with 3D-CRT. It offers increased conformity of dose to the tumor by reducing dose to the sensitive critical structures and allows the clinical implementation of highly conformal non-convex dose distributions.

Multi Leaf Collimators (MLCs) plays a vital role in delivering IMRT. MLC can produce a large number of narrow, closely abutting leaves and regular shaped dose distribution. IMRT fields consist of multiple segments generated from optimization procedures. MLC leaf position controls steep dose gradient. These advances do not come without a risk. Variation between the planned and actual leaf positions can lead to incorrect dose distributions. Radiation treatment outcome is directly related to the performance of the machine that uses MLC in dynamic mode and accuracy in the beam data. These parameters are checked periodically and the results have to be verified with the reference data, obtained during the initial commissioning of the linear accelerator. Stringent QA procedures for dMLC ensure the accuracy of IMRT treatment. Essential to the QA of the intensity modulated dose delivery, is the efficient and accurate comparison of the measured versus calculated dose distribution.

IMRT pretreatment QA and gamma evaluation has performed with amorphous silicon electronic portal imaging devices (EPIDs). The convenience and the reasonable spatial resolution offered by modern EPIDs has stimulated considerable recent research regarding their use as two-dimensional (2D) dosimeters in IMRT pre-treatment verification procedures. The goal of quality assurance (QA) program assure that the machine characteristics do not deviate significantly from their baseline values acquired at the time of acceptance and commissioning. This study is basically to evaluate the quality assurance (QA) procedures, encompassing MLC based IMRT delivery systems, goal-based inverse treatment planning, and clinical implementation of IMRT with plan-specific quality assurance.

Materials and Methods

High energy linear accelerator (Varian Medical Systems, USA) capable of delivering IMRT, VMAT and IGRT, is used in this study. The linac also equipped with 120 leaves MLC (millenium MLC). IMRT planning and treatment are carried out by operating MLCs in dynamic mode (dMLC). The mechanical and dosimetric stability of dMLC were performed; i.e., output stability of dMLC for different sweeping gap widths[1], gravity effect-check for MLC, Dosimetric Leaf Gap and MLC leaf transmissions.

Electronic portal imaging device (EPID) having the configuration of aS1000 and appropriate dosimetric chambers (0.6cc and parallel plate chamber) were used to perform these tests. These tests evaluate the positional as well as dosimetric properties of dMLC. Plan specific QA was performed for 30 plans using EPID. This QA involves dosimetric comparison through gamma evaluation of TPS and machine calculated dose fluence of IMRT plans acquired with EPID.

Results & Discussion

Dosimetric and mechanical QA tests confirm the stability of dMLC. Sweeping field output for various leaf gap widths for 6MV & 15MV has determined and shown consistent results over the period of evaluation (Figure a & b).Gravity effect also verified for dMLC and shown no influence in various gantry angles (Figure c). The leaf transmission for various depths and field sizes were measured and found 1.40% & 1.55% for 6 & 15 MV respectively, which is close to the TPS configured value. The DLG value for 15 MV & 6 MV were 2mm & 1.8mm respectively, it shows good agreement with the reported values ranging from 1.9mm to 2.6mm.

Plan specific QA's has performed with EPID and gamma evaluation (Dose difference & Distance to agreement) has done for various IMRT plans. Average gamma and maximum gamma was analyzed. It has shown good agreement with the gamma criterion (3% & 3mm). Owing to complexity of treatment plans few cases passed the Gamma with 4% & 4 mm criteria.

Conclusion

IMRT is not just an add-on to the current radiation therapy process. It represents a new paradigm that requires the knowledge of various parameters that controls the delivery, such as multimodality imaging, setup uncertainties, internal organ motion, TCP & NTCP, three-dimensional (3-D) dose calculation and optimization, and dynamic beam delivery of non-uniform beam intensities. Therefore, it is essential to evaluate quality assurance procedures on all aspects of IMRT. The overall mechanical & dosimetric aspects of dMLC were stable and consistent over the period of study which gives strong determination to deliver highly complicated IMRT plans. With strict QA program, IMRT can be accurately delivered by dMLC with greater confidence.

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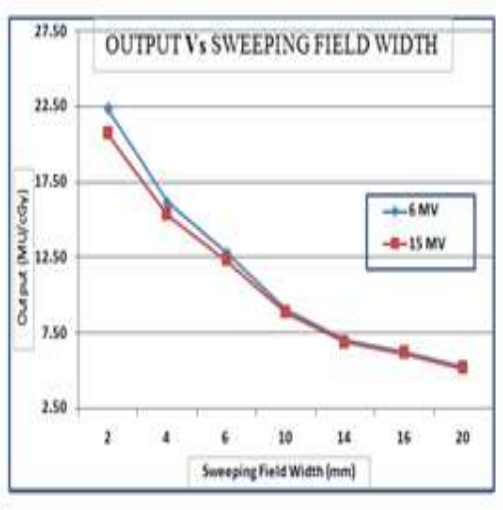

Figure: a

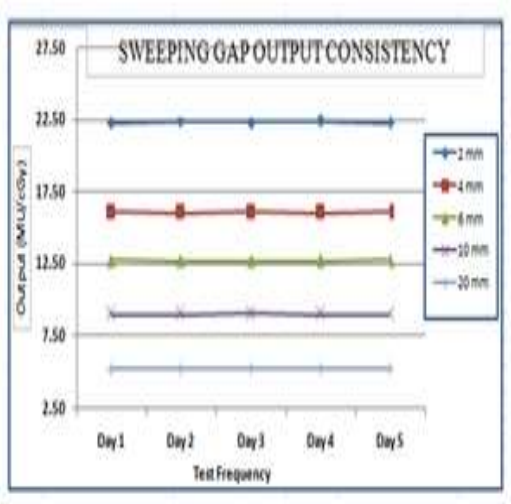

Figure: b

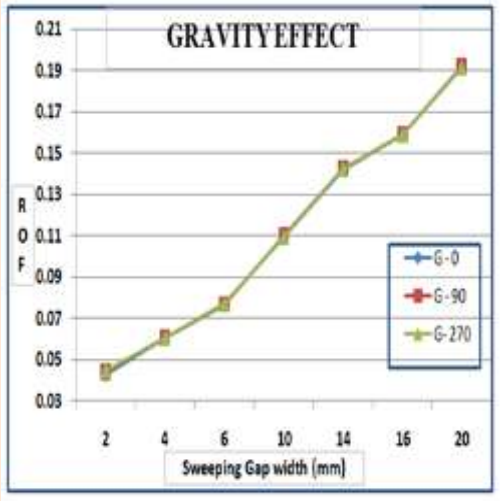

Figure: c

Psychological Impact of Patient Isocentre Shift implemented on 1st day when compared with 2nd,3rd and 4th days

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Introduction

Technology in treatment of cancer is growing to the extent of making it to be a curative disease. Although technology, innovations and research give new hope to the patients, psychological relief to them still remains grey area. This psychological factor due to cancer in patient also affects our treatment to them. In our study we considered this factor affecting patient isocenter shift which we normally do in every departments. We considered two sets where first set with first 3 days and second set with 2nd, 3rd and 4th day patient set up. The detailed setup, study and result are discussed below.

Material and Methods

Our department is equipped with Elekta Compact Linear Accelerator with MV EPID for patient set up verification. In our study, for patient imaging, we considered EPID images for isocenter shift verification. The patient plan was generated in the TPS with respect to beam center. The co-ordinates of X- lateral (Left and right), Y- Longitude (In and Out) and Z- Vertical (Up and Down) were determined from the CT images, which is transferred to the patient for treatment delivery. Normally, co-ordinate shift is applied for the first 3 days of treatment i.e., 1st day, 2nd day and 3rd day. Images are obtained after applying the coordinate shift. From the image information, shift in the coordinate values can be determined. The averaged co-ordinates values can be applied (if the values are below the permissible limit) on forth coming fractions.

In considering for the psychological impact, we apply the beam isocenter shift on first day but without taking imaging, we proceed for treatment.

From 2nd day, 3rd day and 4th day we do shift, take imaging and apply it. This three days co-ordinate values are the averaged as normal procedure. By this way we can evaluate the psychological impact in patient shift. The values obtained are discussed below.

Results & Conclusion

The results are show in table 1, 2 and 3 respectively. We have considered 5 pelvis, 5 head and neck, 5 brain tumor patients for this study. We noticed that there is a significance change in the patient positioning in all three directions (X, Y and Z) with respect to 1st day and 2nd day itself. Hence, it is suggested that if a patient is more excited on first day treatment, the average co-ordinate shift for the patients may be considered from the second day of treatment. In each case, only 5 patients were considered for this study, the precise conclusion cannot be arrived with this sample. We require more patient details to recommend this method to other departments

Table 1: Pelvis

Patient	1st day Set Up (mm)	2nd day Set Up(mm)	3rd Day Set Up (mm)	4th Day Set Up (mm)
1.	X= 0.18, Y=0.8, Z=0.82.	X= 0.24, Y=0.39, Z=0.36.	X=0.15, Y=-0.05, Z=-0.38.	
		X= 0.24, Y=0.39, Z=0.36.	X=0.15, Y=-0.05, Z=-0.38	X=0.20, Y=-0.12, Z=-0.34
2.	X= 0.45, Y=-0.35, Z=0.44.	X= 0.30, Y=-0.13, Z=-0.11.	X=0.10, Y=-0.22, Z=0.15	
		X= 0.30, Y=-0.13, Z=0.11.	X=0.10, Y=-0.22, Z=0.15	X=0.20, Y=-0.20, Z=0.18
3.	X= 0.45, Y=0.36, Z=0.16	X= 0.35, Y=0.30, Z=0.10.	X= 0.28, Y=0.32, Z=0.23.	
		X= 0.35, Y=0.30, Z=0.10.	X= 0.28, Y=0.32, Z=0.23.	X= 0.30, Y=0.25, Z=0.18.
4	X= -0.30, Y=0.99, Z=0.33.	X= 0.59, Y=-0.58, Z=-0.55.	X= 0.60, Y=-0.22, Z=-0.10.	
		X= 0.59, Y=-0.58, Z=-0.55.	X= 0.60, Y=-0.22, Z=-0.10.	X= 0.67, Y=-0.39, Z=-0.22.
5	X= -0.24, Y=0.09, Z=0.68.	X= 0.39, Y=-0.30, Z=-0.39.	X= 0.24, Y=0.16, Z= -0.21.	
		X= 0.39, Y=-0.30, Z=-0.39.	X= 0.24, Y=0.16, Z= -0.21.	X= 0.26, Y=0.30, Z= -0.36.

Table 2: Head & Neck patients

Patient	1st day Set Up (mm)	2nd day Set Up (mm)	3rd Day Set Up (mm)	4th Day Set Up (mm)
1.	X= 0.17, Y=0.03, Z=0.15.	X= 0.0, Y=-0.11, Z=0.07.	X=0.0, Y=-0.02, Z=-0.0.	
		X= 0.0, Y=-0.11, Z=0.07.	X=0.00, Y=-0.02, Z=-0.0.	X=0.14 Y=-0.10, Z=-0.17.
2.	X= 0.13, Y=-0.21, Z=-0.37.	X= 0.17, Y=-0.07, Z=-0.12.	X=0.02, Y=-0.11, Z=0.28	
		X= 0.17, Y=-0.07, Z=-0.12.	X=0.02, Y=-0.11, Z=-0.28	X=0.21, Y=-0.19, Z=-0.25.
3.	X= 0.03, Y=-0.43, Z=0.0.	X= 0.0, Y=0.10, Z=-0.11.	X= 0.10, Y=-0.12, Z=0.05.	
		X= 0.0, Y=0.10, Z=-0.11.	X= 0.10, Y=-0.12, Z=0.05.	X=0.22, Y=-0.19, Z=0.11
4	X= 0.54, Y=-050., Z=-0.38.	X= 0.32, Y=-0.07, Z=-0.15.	X= 0.07, Y=-0.10, Z=-0.01.	
		X= 0.32, Y=-0.07, Z=-0.15.	X= 0.07, Y=-0.10, Z=-0.01.	X=0.22, Y=-0.17, Z=-0.23.
5	X= 0.10 Y=0.03, Z=-0.33	X= -0.06, Y=-0.09, Z=-0.23.	X= 0.0, Y=-0.03, Z= -0.20.	
		X= -0.06, Y=-0.09, Z=-0.23.	X= 0.0, Y=-0.03, Z= -0.20.	X=0.02, Y=-0.11, Z=-0.18

Table 3: Brain tumor patients

Patient	1st day Set Up (mm)	2nd day Set Up (mm)	3rd Day Set Up (mm)	4th Day Set Up (mm)
1.	X= 0.25, Y=-0.36, Z=-0.18.	X= 0.06, Y=-0.22, Z=-0.03.	X=0.07, Y=0.11, Z=-0.09.	
		X= 0.06, Y=-0.22, Z=-0.03.	X=0.07, Y=0.11, Z=-0.09.	X=0.13, Y=0.21, Z=-0.18.
2.	X= 0.07, Y=-0.59, Z=0.0.	X= 0.02, Y=-0.39, Z=0.0.	X=-0.03, Y=-0.24, Z=-0.05	
		X= .02, Y=-0.39, Z=0.0.	X=-0.03, Y=-0.24, Z=-0.05	X=-0.10, Y=-0.26, Z=-0.16
3.	X= 0.42, Y=-0.58, Z=0.06	X= 0.24, Y=-0.40, Z=0.0.	X= 0.12, Y=-0.27, Z=0.17.	
		X= 0.24, Y=-0.40, Z=0.0.	X= 0.12, Y=-0.27, Z=0.17.	X= 0.19, Y=-0.30, Z=0.10.
4	X= 0.27, Y=-0.03, Z=0.01.	X=0.07, Y=0.02, Z=0.05.	X= 0.00, Y=0.0, Z=0.0.	
		X=0.07, Y=0.02, Z=0.05.	X= 0.0, Y=0.0, Z=0.0.	X= 0.1, Y=0.12, Z=0.09.
5	X= 0.38 Y=0.02, Z=0.0.	X= 0.28, Y=0.06, Z=-0.10.	X= 0.0, Y=0.08, Z= -0.16.	
		X= 0.28, Y=0.06, Z=-0.10.	X= 0.0, Y=0.08, Z= -0.16.	X= 0.15, Y=0.12, Z= -0.21.

Quality assurance of simultaneous treatment of multiple targets planned with mono isocenter using 3DCRT technique

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Objective

The objective of this study is to validate a mono isocentric plan generated by 3DCRT technique in terms of dose conformity and coverage for the treatment of multiple metastatic lesions using composite point dose method and two dimensional (2D) ion chamber array detector.

Methods and Materials

Four patients having multiple metastatic lesions (targets) which are covered in the region of multi leaf collimator (MLC) were selected for this study. Clinical descriptions of individual cases are a) Carcinoma of lung with bilateral hip bone and femoral metastases where both targets lie along the transverse plane, b) Carcinoma right lung with vertebral metastases where both targets lie along longitudinal plane, c) Renal cell carcinoma with pubic and acetabular metastases where both targets lies in different planes and d) Carcinoma of penis post partial penectomy with bilateral inguinal & one vertebral metastatic lesions where the inguinal targets are in different plane with respect to the vertebral target. A dose of 30 Gy in 10 fractions was prescribed to the 100% isodose line that is covering the targets. All patients were planned for palliative radiotherapy using mono isocenter 3DCRT technique. CMS XiO® Treatment Planning System (TPS) was used for dose calculations. Treatments were executed with medical linear accelerator (M/s Elekta Compact), using 6 MV photon beam.

Quality assurance (QA)

a) TPS QA

To evaluate the dosimetric performance of the TPS with 3D dose calculation algorithm using the basic beam data measured for 6 MV X-rays, simple test cases (*involve simple field arrangements as well as the presence of a low-density material in the beam to resemble an air in-homogeneity*) to complex ones *(the presence of in-homogeneity, beam modifiers or beam modifiers with asymmetric fields)* were created according to the Technical Report Series-430 in a homogeneous water phantom. Absolute dose measurements were performed for the each case with the MU calculation given by the TPS and the measured dose is compared with the corresponding calculated dose values.

b) Phantom arrangements for simulation

For point dose verification (Composite dosimetry) of above generated plans, same patient geometry was simulated by three water equivalent phantoms [two identical water phantoms (having dimensions of 30 cm × 15 cm × 15 cm each) which are routinely used for beam quality index measurements. All phantoms had a provision of inserting 0.65 cc farmer type ionization chamber (IC) sleeve. They were arranged in four different combinations in order to generate four QA plans that simulate actual patients target geometry. Computed Tomography (CT) scans were acquired along with ICs placed inside the sleeves of the phantoms and images were transferred to the contouring station. The chamber positions were contoured as IC-1, IC-2& IC-3 in the scanned images which simulated the targets in an actual patient. Isocenter was chosen at the centre of combined target that was generated with a 5mm margin encompassing both IC-1 & IC-2 (in two targets case) and IC-1, IC-2 & IC-3 (in three targets case).Contoured CT data set were transferred to CMS Xio TPS for beams placement and dose calculations.

c) Beam placements and dose calculations

A group of four main beams with gantry angles 0^0, 90^0,$180^0$and 270^0 were placed taking centre of combined target as isocenter in all QA plans. Beams were conformed to the respective targets (ICs). In order to obtain uniform dose distribution around the targets, appropriate beam weights, weight points and different wedge angles were chosen.

Beam weights were adjusted until the optimum coverage and acceptable hot spots were achieved. A dose of 3.0 Gy was prescribed to the 100% isodose line that is covering all the targets. By viewing the 105% dose cloud in a beam's eye view projection of the treatment fields, subfields were designed by blocking the volume of targets receiving greater than 105% of the prescribed dose, and the beam weightage was adjusted among sub and main fields in order to achieve the uniform dose distribution. Figure 1 shows the 95% isodose distribution that covers around targets of a QA plan of corresponding patient.

d) Plan Evaluation

Plan evaluation was done using dose volume histogram (DVH) in terms of conformity index (CI) and homogeneity index (HI), maximum and mean doses (D_{max} and D_{mean}) to target.

e) Point dose verification

The generated QA plans were exported to Mosaiq® record and verification system and were scheduled for point dose verification. All measurements were carried out with phantoms and ICs placed inside the sleeves which were connected to the electrometers. Scheduled QA plans were executed under linear accelerator and the charge collected (M) from each electrometer was converted to absorbed dose.

f) Two dimensional (2D) dose verification

A two dimensional (2D) ion chamber array detector (Model: I'mRT MatriXX, M/s Iba dosimetry, Germany) was used for planar dose verification. Generated verification plan was exported and executed using Mosaiq® record and verification system for planar dose verification with I'mRT MatriXX device. The beam central axis was made perpendicular to the I'mRT MatriXX measurement level at the center of the measurement area during the measurement. By executing the verification plan, the cumulative fluence at the detector plane was calculated and transferred to the Omnipro software for comparison.

Results & Discussion

As observed, D_{max}, D_{mean}, CI and HI values with standard deviation around the targets in all QA plans were 3.09±0.02 Gy, 3.03±0.02 Gy, 0.96±0.03 and 0.04±0.03 respectively. Point dose measurements to all ICs were obtained using N_{DW} based formalism and compared with the calculated values from TPS in all QA plans are shown in Table 1. It was observed that the percentage deviation of measured dose obtained for all targets were within ±2.0% against calculated values from TPS in all QA plans. A pass percentage of 97% was obtained with the set criteria of 3mm distance to agreement (DTA) and 3% dose difference for fluence verification around the targets in QA plans.

Conclusion

Our investigation of dosimetric performance and treatment delivery efficiency suggests that simultaneous treatment of multiple targets with single isocenter in 3DCRT technique is a better option. The results of composite point dosimetry in this study were in agreement with the TPS calculated dose, at the same time achieving the required coverage as in other sophisticated techniques and higher state of art equipment in the field of Radiotherapy. This technique can be further implemented with different doses to individual targets in same the plan that can significantly help in radiobiological control of gross and distant lesions (if any). Evaluation of 3DCRT with higher end treatment modalities with more number of patients (having multiple targets) treated by mono-isocentric technique is the scope of further study.

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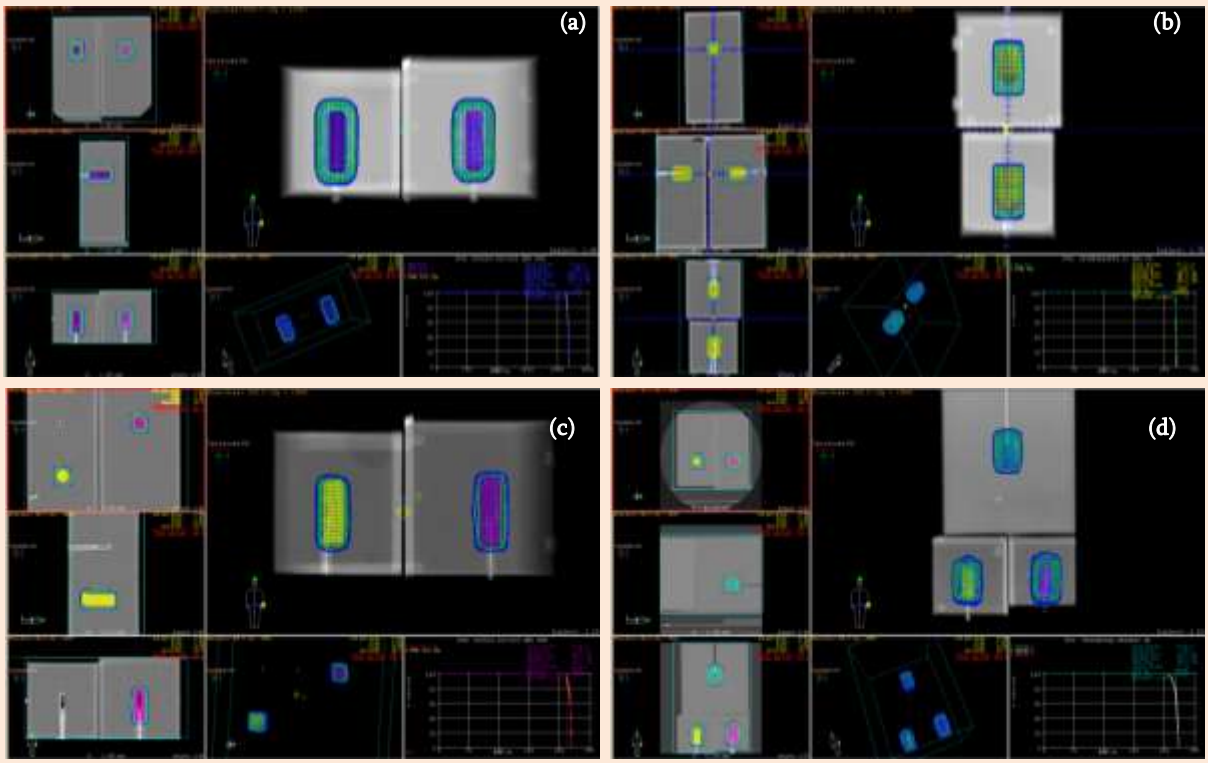

Figure.1: 95% isodose distribution that covers around targets in QA Plans of corresponding patient with (a) where both targets lie along the transverse plane (b) where both targets lie along longitudinal plane (c) wherebothtargets lies in different planes and (d) where the inguinal targets are in different plane with respect to the vertebral target.

Table 1 : Percentage deviation between measured and TPS calculated dose

	Measured Mean dose (Gy) = M × TCF@			TPS calculated Mean dose (Gy)			Percentage Deviation (%)		
QA Plan	IC-1	IC-2	IC-3	IC-1	IC-2	IC-3	IC-1	IC-2	IC-3
a	2.97	2.99	NA	3.03	3.03	NA	1.98	1.32	NA
b	3.07	3.01	NA	3.04	3.04	NA	-0.99	0.99	NA
c	3.02	3.07	NA	3.02	3.01	NA	0.00	-1.99	NA
d	3.11	3.10	3.06	3.08	3.04	3.02	-0.97	-1.97	-1.32

@TCF = Total Correction Factor ($N_{DW} \times K_{TP} \times K_{pol} \times K_{Sat} \times K_{Q,Q_0}$)[14]

NA: Not Applicable to the QA plan.

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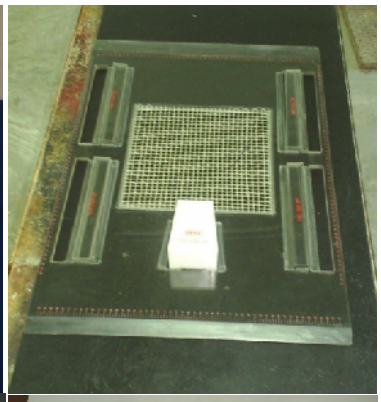

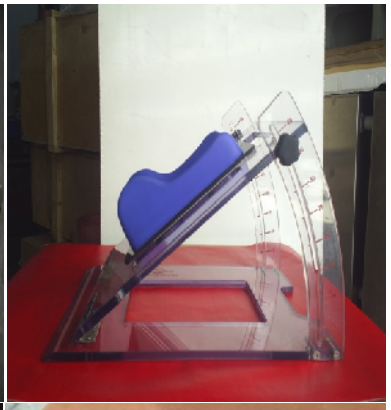



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