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Surface Dose Measurements on an Indigenously Made Inhomogeneous Female Pelvic Phantom Using Metal-Oxide-Semiconductor-Field-Effect-Transistor Based Dosimetric System

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ABSTRACT

Introduction: Megavoltage X-ray beams are used to treat cervix cancer due to their skin-sparing effect. Preferably, the radiation surface doses should be negligible; however, it increases due to electron contamination produced by various field parameters. Therefore, it is essential to provide proper knowledge about the effect of different field parameters on radiation doses. This study sought to find out the effect of various physical parameters on the surface doses.

Materials and Methods: The effects of field size, source-to-surface distance, and open or acrylic block tray fields on surface doses were determined. Metal-Oxide-Semiconductor-Field-Effect-Transistor based dosimetric system was used for dose measurements for 6 MV photon beam. The directly measured radiation surface doses on pelvic phantom were compared to surface dose values computed by treatment planning system in the similar field parameters.

Results: The measured results for the percentage depth dose (PDD_0) in field size of 10x10 cm^2 were 13.32%, 12.95% and 13.87% for open field and 36.87%, 36.31% and 35.88% for acrylic block tray field. In addition, the computed doses were 7.83%, 7.73% and 7.65% for open field and 16.33%, 16.12% and 15.88% for acrylic block tray field at 80 cm, 100 cm, and 120 cm SSDs, respectively.

Conclusion: The surface dose increases along with the size of the field and decreases with increasing SSD. The surface doses in acrylic block tray fields were significantly higher than the open ones. The treatment planning system computed a lesser radiation doses in same field parameters.

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Introduction

In radiotherapy, high energy photon beams are used for treating the carcinoma cervix patients. High energy photon beams are deposited maximum radiation dose to the deep seated tissues and negligible dose to surface, this phenomenon is called skin-sparing effect [1]. But generally, these photon beams are contaminated by electrons and low energy photons till they reach the surface and they lead to increase surface dose [2, 3]. The surface dose also increases due to backscatter radiation.

There are also other radiation field setup parameters which increase the surface radiation dose viz. field size, the beam modifiers and source-to-surface distance (SSD) etc. [4, 5]. While a proper treatment plan, it is essential to provide proper knowledge about the effect of different field parameters on the surface dose. Excessive surface radiation dose can create skin malignances and degrade the quality of life in the patients with cervical cancer.

Generally, surface dosimetry is usually performed on flat surface of a phantom. Nonetheless, the surface of pelvic region is irregular in shape, and the lateral curve of female pelvic is convex. In this study, the surface doses were measured on the surface of an indigenously made female pelvic phantom, which created more realistic surface dosimetric condition. This study is aimed to find out effects of various field parameters on pelvic surface doses using metal-oxide-semiconductor-field-effect-transistor (MOSFET) based dosimetric system and an indigenously made inhomogeneous female pelvic phantom.

Materials and Methods

Surface dose of a 6 MV X-ray photon beam was measured in various field sizes and open and solid acrylic block tray fields. Primus linear accelerator (Siemens make, Germany,) which has 29 pairs of leaves in the multileaf collimator, was used to generate 6 MV photon beam.

Metal-Oxide-Semiconductor-Field-Effect-Transistor based dosimetric system (Best Medical, Canada) was utilized to measure the surface doses on the female pelvic phantom [6-9]. In this dosimetric system, a

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battery-operated wireless reader was connected to MOSFETs (TN-502 RD) to interact with advanced dose readout software. Several characteristics of these MOSFETs include, having one calibration factor for all photon and electron modalities, as well as miniature active dose region, and being isotropic within ±2% for 360° limits and temperature and dose rate independent, etc [10].

Indigenously made inhomogeneous female pelvic phantom was designed and developed as a tissue equivalent pelvic phantom that mimicked Indian female pelvic dimensions. It was produced using locally available chemical compositions to achieve a cost-effective phantom with similar physico-radiological properties as real human pelvic tissues. Real bones of female cadavers such as the pelvic girdle, femur, and vertebrae were embedded to prepare the phantom.

Paraffin wax amalgamated in suitable composition with Aloe-vera powder, purified borax and sodium benzoate were used to obtain optimal density and effective atomic number effects. The physical dimensions of the female pelvic phantom were comparable with mean dimensions of Indian female pelvis. This tissue equivalent phantom was radiologically equivalent to Indian human female pelvis in all respects. The mean computed tomography numbers were 39.9HU, 30.5HU, 24.7HU, 34.6HU, -86.8HU, 578.6HU, and -220.9HU for uterus, bladder, rectum, muscles, fat, bone, and air cavities, respectively. Relative electron densities of muscle, fat and bones of the phantom were 1.035HU, 0.913HU, and 0.779HU respectively that were comparable with the values of female pelvic tissues (Figure 1).

Figure 1. Indigenously made inhomogeneous female pelvic phantom

The CT-slices (3 mm thickness) of an indigenously made female pelvic phantom were taken by Siemens Somatom Emotion- 16 Slice CT-Simulator and exported to treatment planning system (TPS) to generate the treatment plans. Oncentra 3-dimensions TPS, version 4.3 with external and brachytherapy planning licenses was used for surface dose computation on pelvic phantom in same dosimetric parameters, in which direct surface dose was measured. Convolution-superposition algorithm was used for dose computation by TPS.

In this study, the percentage depth doses for open and with 1.0 cm thick solid acrylic block tray fields were measured in different field sizes including 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2, 25x25 cm^2 at the SSDs of 80 cm, 100 cm and 120 cm. The readings at the surface (depth = 0) of the phantom were normalized to the maximum depth dose for the individual field setup (Figure 2).

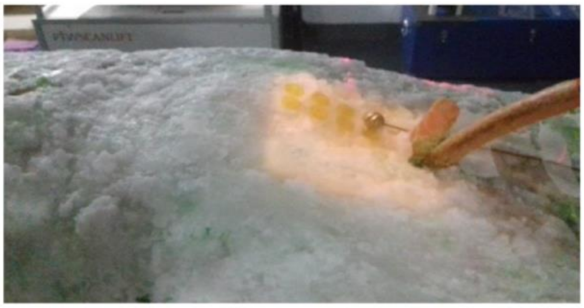

Figure 2. Setup for percentage depth dose measurements on pelvic phantom

Results

The PDD_0 of a 6 MV photon beam was measured at surface for open and solid acrylic block tray at various SSDs in different field sizes (Table 1).and percentage depth dose was computed by treatment planning system on pelvic phantom surface for same dosimetric setup such as direct surface PDD_0 measurements.

It was found that the percentage depth dose on surface (PDD_0) increased along with the field size; however, it decreased by increasing the SSD for both open and solid acrylic block tray fields.

The measured PDD_0 of a 6 MV photon beam in the field size of 5x5 cm^2 were 9.73%, 9.51% and 9.43% for open field and 20.53%, 19.72% and 19.13% for acrylic block tray field at the SSDs of 80 cm, 100 cm, and 120 cm, respectively. Similarly, the measured PDD_0s of a 6 MV at a 10x10 cm^2 field size were 13.32%, 12.95% and 12.87% for open field and 36.87%, 36.31% and 35.88% for block tray field at the SSDs of 80 cm, 100 cm, and 120 cm, respectively.

The measured PDD_0s of a 6 MV photon beam in 15x15 cm^2, 20x20 cm^2, and 25x25 cm^2 field sizes are stated in the Table 1. The TPS computed the PDD_0 in the same dosimetric conditions such as beam energy, field size, and SSD, Table 1

TPS computed PDD_0, of a 6 MV photon beam at a 5x5 cm^2 field as 7.32%, 7.17%, and 7.02% for open field and 11.53%, 11.23% and 10.97% for acrylic block tray field at the SSDs of 80 cm, 100 cm, and 120 cm, respectively.

The TPS computed the PDD_0, of a 6 MV photon beam in a 10x10 cm^2 field size as 7.83%, 7.73%, and 7.65% for open field and 16.53%, 16.12%, and 15.88% for acrylic block tray field at the SSDs of 80 cm, 100 cm, and 120 cm, respectively.

Furthermore, the TPS computed the PDD_0, of a 6 MV photon beam in the 15x15 cm^2, 20x20 cm^2, and 25x25 cm^2 field sizes Table 1.

Table 1. Direct measured and TPS* computed percentage depth dose at phantom surface for 6 MV, open and solid acrylic tray fields at the source-to-surface distances of 80 cm, 100 cm and 120 cm in different field sizes

Field Size	Measured PDD** on Pelvic Phantom Surface						Computed PDD on Pelvic Phantom Surface					
	Open Field (SSD)			With Tray Field (SSD)			Open Field (SSD)			With Tray Field (SSD***)		
	80 cm	100 cm	120 cm	80 cm	100 cm	120 cm	80 cm	100 cm	120 cm	80 cm	100 cm	120 cm
5x5	9.73	9.51	9.43	20.53	19.72	19.13	7.32	7.17	7.02	11.53	11.23	10.97
10x10	13.32	12.95	12.87	36.87	36.31	35.88	7.83	7.73	7.65	16.53	16.12	15.88
15x15	20.97	20.33	20.15	39.73	38.21	37.92	12.52	12.37	12.03	19.39	18.30	16.99
20x20	29.52	28.79	28.17	52.31	49.52	48.13	15.52	15.37	15.11	20.95	20.13	19.57
25x25	37.32	35.93	35.42	68.52	65.93	65.47	18.19	18.01	17.49	23.25	22.83	22.55

*Treatment planning system, **Percentage depth dose, ***Source-to-surface distance

Discussion

Measured PDD$_0$ Data

According to the results, the percentage difference in the PDD$_0$s of open field with the sizes of 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2, and 25x25 cm^2 were 2.31%, 2.86%, 3.14%, 2.54%, and 3.87% between 80 cm and 100 cm SSDs, and similarly, 0.84%, 0.62%, 0.89%, 2.20%, and 1.45% between 100 cm and 120 cm.

The maximum percentage difference between the SSDs of 80 cm and 100 cm considering the PDD$_0$ was 3.87% in the field size of 25x25 cm^2 field size. Furthermore, the difference between the SSDs of 100 cm and 120 cm was 2.20% in the field size of 20x20 cm^2 field size. These results were in agreement with the results obtained by Butson et al., which mentioned 4% percentage difference between the SSDs of 80 cm and 100 cm in terms of PDD$_0$ in the field size of 25x25 cm^2 [11].

The percentage difference between the SSDs of 80 cm and 100 cm in terms of PDD$_0$ for solid acrylic block tray field in the sizes of 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2, and 25x25 cm^2 were 4.11%, 1.54% 3.97%, 5.63%, and 3.93%, respectively. Moreover, the percentage difference between 100 cm and 120 cm were 3.08%, 1.19%, 0.76%, 2.89%, and 0.71%, respectively.

The maximum percentage difference in PDD$_0$ for tray field was 5.63% between the SSDs of 80 cm and 100 cm in the field size of 20x20 cm^2 field size and 3.08% between the SSDs of 100 cm and 120 cm SSDs in the field size of 5x5 cm^2.

In the field size of 10x10 cm^2 at the SSD 80 cm, in the presence of solid acrylic tray PDD$_0$ was 36.87% and in the field size of 15x15 cm^2, it was 39.73% at the SSD of 80 cm. These results were consistent with the results obtained by Tannous et al. [12]. The surface doses for acrylic solid block tray field were higher than those for the open fields. This effect was dominant in larger field sizes and at lower SSDs.

TPS Computed PDD$_0$ Data

Similarly, percentage difference in percentage depth doses at phantom surface for open field, 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2, 25x25 cm^2 field sizes were 2.09%, 1.29%, 1.21%, 0.98%, and 0.99% between 80 cm and 100 cm SSDs and 2.14%, 1.05%, 2.82%, 1.72%, and 2.97% between 100 cm and 120 cm SSDs were found.

The percentage difference in the PDD$_0$ for solid acrylic block tray field, in the field sizes 5x5 cm^2, 10x10 cm^2, 15x15 cm^2, 20x20 cm^2, and 25x25 cm^2 were 2.67%, 2.54% 5.95%, 4.07%, and 1.84% between the SSDs of 80 cm and 100 cm and 2.37%, 1.51%, 7.71%, 2.86%, and 1.24% between the SSDs of 100 cm and 120 cm.

The surface doses computed by the TPS were significantly different from the dose measured directly on the phantom surface. This shows that the TPS gives the under doses in case of pelvic surface dosimetry.

Conclusion

The PDD$_0$s measured on female pelvic phantom are more accurate because this phantom created more realistic surface dosimetric conditions than flat surface phantoms. The acrylic block tray fields significantly increased the surface doses in comparison to open fields due to influence of electron contamination produced by blocking tray. The surface dose decreased with the increase of SSD for a given field size; however, it increased with the field size.

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