Original Research Paper

Volume-7 | Issue-9 | September-2017 | ISSN - 2249-555X | IF : 4.894 | IC Value : 79.96

Medical Physics

STUDY THE EFFECT OF PELVIC HETEROGENEITIES ON RECTUM DOSE MEASUREMENTS INSIDE AN INDIGENOUSLY MAKE FEMALE PELVIC PHANTOM AND RANDO FEMALE PELVIC PHANTOM USING MOSFET DOSIMETERS

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ABSTRACT **Background:** Human body consists of variety of heterogeneous tissues. Pelvis is the most heterogeneous regions viz. bones, soft tissues, fat, air cavities, faecal matter, urine etc. These heterogeneities lead to different attenuation for defined source energy. For the success of radiotherapy treatment in female pelvic cancers, there is a need to study the effect of tissue heterogeneities on dose distribution inside the tumor and adjacent normal tissues.

Objective: The aim of this study is to compare the direct measure rectal doses at various points inside an indigenously make inhomogeneous female pelvic phantom and Rando female pelvic phantom using in-vivo dosimeters and authenticate the heterogeneity correction algorithm by direct measurements.

Materials and Methods: MOSFET dosimetric system is used for dose measurements at different rectal points in female pelvic phantoms. Both phantoms are scanned on CT-Simulator (Siemens make) in 5 mm thick slices which are exported to treatment planning system (TPS). Intra-cavitary brachytherapy plans are generated as per ICRU 38 and export to HDR brachytherapy machine and then planned doses are measured directly at various rectal points.

Results: The rectum is a hollow pipe filled with air and faecal matter and surrounded by various heterogeneous tissues. The results indicate that the dose measured in the both female pelvic phantoms are in the range of 15-21% lower than the dose calculated by the TPS at the same rectal points.

Conclusion: The treatment planning system is overestimated the rectum dose. Therefore, the direct dose measurements in phantoms are useful for understanding the actual treatment conditions and post radiotherapy treatment complications.

KEYWORDS : Heterogeneities, Rectal dosimetry, MOSFET dosimetric system, Brachytherapy

INTRODUCTION:

Human body not only consists of water but also it has various heterogeneous tissues and cavities which affect the radiation dose distribution inside the target region and in the critical organs lie in the vicinity of target. As we know, the carcinoma cervix is the second commonest cancer in the Indian females and the pelvic region is also the highest heterogeneous region amongst other parts of the body. Therefore, pelvic heterogeneities have very high potential to alter radiation doses inside the target as well as adjacent critical organs. The teletherapy and brachytherapy are the two ways of delivering the radiation to the cancer patients. In brachytherapy, small encapsulated radioactive sources are used inside or at a short distance from the target volume for radiation of malignant tumors.[1]

The success of the radiotherapy depends on the accuracy in radiation dose delivery which is essential for disease free survival or least complications to the patients. Therefore, it is necessary to correct water phantom dosimetric data for tissue heterogeneities correction before implementation on cancer patients undergoing radiotherapy treatment.

For uterine cervix carcinoma patients, brachytherapy provides greater dose uniformity in the target volume by low-energy radioactive source and the dose reduces drastically to surrounding healthy tissues because dose reduction follows inverse square law with distance. This is the beauty of brachytherapy treatment.

The use of Iridium-192 source, in high dose rate (HDR) remote After Loading brachytherapy is increasing because of the ability to reduce the treatment time, more control over the dose delivery process and the ability to provide safer radiation protection. The high dose delivery per treatment session, it is important to ensure the accuracy of the dose received by target and the surrounding healthy tissues. The dose in brachytherapy treatment is calculated by The American Association of Physicists in Medicine (AAPM, TG43) protocol in which the dose is measured in a homogeneous water phantom.[2] The potential drawback of AAPM, TG-43 protocol is the failure to take into account the effect of tissue heterogeneities (viz. bone, soft tissues, air etc.)

For tissue heterogeneity correction, there are various mathematical model based algorithms available in the treatment planning system, but the validation of algorithms are very necessary through direct dosimetry in heterogeneous phantoms.

Kwan et al. (2009) examined the assumption of homogenous water-equivalent rectum of unlimited size as well as the effect of empty or filled rectal cavity on the dose absorbed on the rectal wall using Monte Carlo simulation. The results showed that the dose in the rear wall of the rectal cavity is 22%-26% higher than the dose measured in a filled rectal cavity.[3]

Brachytherapy of uterine cervix carcinoma often results in under-dosing or over-dosing to surrounding structures, such as rectum and bladder. Therefore, it is important to quantify the delivered dose to these organs. The rectal toxicity depends on the total radiation dose, received by the rectum, irradiated rectal volume, and the treatment dose rate.[4,5] However, the incidence and amount of subsequent rectal compilations mainly depend on the total radiation dose delivered to the rectum.[6]

For the dosimetry of brachytherapy requires very accurate small dosimeters because of the sharp dose gradients (better resolution for dose reporting, especially in the sharp drop dose region). On the other hand, dosimetry in heterogeneous area is so complicated in practice. Therefore, the dosimeter should have high spatial resolution, energy independence, tissue equivalency, and convenience of use.[7]

Thus the aims of present study are to measure the rectum doses at the pre-defined points using MOSFET dosimetric system in an indigenously make in-house heterogeneous female pelvic phantom and Rando female pelvic phantom and also authenticate the computational capability of treatment planning system on the basis of percentage dose differences.

MATERIALS AND METHODS

Calibration of MOSFET Dosimeter in Ir-192 Source:

A portable MOSFET dosimetric system with two MOSFETs (TN-502RD-H SN: 33545 & SN: 33546) and a electrometer (Best Medical Canada make), microSelectron HDR with Ir-192 source, Oncentra 3D-TPS with brachytherapy license, Somatom Emotion 16 Slice CT Simulator (Siemens make) and an acrylic cylindrical phantom are used for calibration & angular dependence of MOSFET's dosimetric system. An acrylic cylindrical phantom with a center at hole and four holes in perimeter at 0°, 90°, 180° and 270° is scanned for 5 mm slices with MOSFET dosimeters and the data is exported to treatment planning system. The brachytherapy plans are generated in which Ir-

192 source is placed at a single dwell position in the center hole and prescribed doses as 700 cGy and 900 cGy at MOSFET's predetermined positions respectively. MOSFET dosimeter (in standard bias) is kept in perimetric holes and recorded the doses online. Figure 1. shown the calibration setup of MOSFET dosimetric system.

Figure 1: Calibration of MOSFET dosimeter in Ir-192 source

RECTAL DOSIMETRY IN AN INDIGENOUSLY MAKE FEMALE PELVIC PHANTOM:

An indigenously make heterogeneous female pelvic phantom is scanned on CT- Simulator for 5 mm thick slices and these slices are exported to Oncentra 3D-TPS. Then an intra-cavitary brachytherapy plan is generated as per ICRU-38 and export to microSelectron HDR brachytherapy machine.[8] then pelvic phantom with applicator is connected with brachytherapy machine by transfer tubes. The MOSFET dosimeter is placed at pre-defined points in rectum and measured the dose values. Figure 2. shown the rectal dosimetric setup in an indigenously make female pelvic phantom.

Figure 2: Rectal dosimetry in an indigenously make female pelvic phantom

RECTAL DOSIMETRY IN A RANDO FEMALE PELVIC PHANTOM

Similarly, a Rando female pelvic phantom (make ATOM® Dosimetry Phantom, CIRS, USA) is scanned on CT-Simulator for 5 mm slices thickness and these slices are exported to Oncentra 3D treatment planning system. The phantom with applicator is connected with brachytherapy machine. The MOSFET dosimeter is placed at pre-defined points and measures the dose values. Figure 3. shows the rectal dosimetry setup in a Rando female pelvic phantom.

Figure 3: Rectal dosimetry in a Rando female pelvic phantom

RESULTS

CALIBRATION OF MOSFET DOSIMETRIC SYSTEM FOR HDR BRACHYTHERAPY SOURCE (Ir-192) USING ACRYLIC CYLINDRICAL PHANTOM

The dosimetric characteristics of the portable MOSFET dosimetric system are studied. The calibration factors are found 0.978 cGy/mV and 0.984 cGy/mV for MOSFET SN: 33545, exposed with 700 cGy and 900 cGy in cylindrical phantom respectively. Similarly, the calibration factors (MOSFET SN: 33546, exposed with 700 cGy and 900 cGy in cylindrical phantom) are 1.0895 cGy/mV and 1.1203 cGy/mV respectively. The angular dependence of both the MOSFETs is also studied, it is within 2% for the given doses of 700 cGy and 900 cGy, and it compares well with the observations of the other investigators.[9,10,11]

COMPUTATIONAL AND MEASURED RECTAL DOSES IN AN INDIGENOUSLY MAKE FEMALE PELVIC PHANTOM

Table 1. depicts the results of rectal dosimetry in indigenously make female pelvic phantom. Assuming, nine points in a line within rectum, the distance between two adjacent points is 5mm, MOSFET dosimeter is kept one by one at each point and recorded the correct dose values. The percentage dose differences are calculated between computational and measured doses. The percentage dose differences are found to be in the range of 15-18%.

Figure 4. shows the graphical representation of percentage dose difference for rectal dosimetry in an indigenously make female pelvic phantom.

Table 1: Computational and measured dose values in indigenously make female pelvic phantom with percentage dose differences.

Rectal dosimetry in indigenously make female pelvic phantom			
Dose points in rectum	Computational Dose values (cGy)	Measured Dose Values (cGy)	Percentage difference (%)
1.	315	271	15.01
2.	335	285	16.12
3.	355	299	17.12
4.	365	298	20.21
5.	362	302	18.07
6.	300	252	17.39
7.	287	242	17.01
8.	276	235	16.04
9.	260	222	15.76

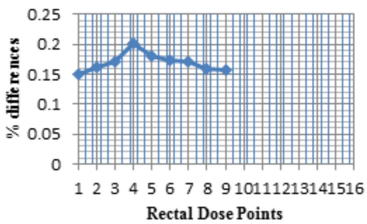

Figure 4: Percentage dose difference of computational and measured rectal doses in indigenously make female pelvic phantom

COMPUTATIONAL AND MEASURED RECTAL DOSES IN A RANDO FEMALE PELVIC PHANTOM

Table 2. shows the rectal dosimetric results in a Rando female pelvic phantom. Similarly, assuming nine points in a line within rectum and the percentage dose differences are calculated between computational and measured doses. The percentage dose difference is found to be in the range of 18-21% and Figure 5. shows the graphical representation of percentage dose difference for rectal dosimetry in a Rando female pelvic phantom.

Table 2. Computational and measured dose values in Rando female pelvic phantom with percentage dose differences

Rectal dosimetry in Rando female pelvic phantom			
Dose points in rectum	Computational Dose values (cGy)	Measured Dose Values (cGy)	Percentage difference (%)
1	344	287	18.06
2	356	295	18.74
3	367	302	19.43
4	369	300	20.62
5	360	295	19.84
6	355	291	19.81
7	340	282	18.64
8	338	280	18.77
9	335	278	18.59

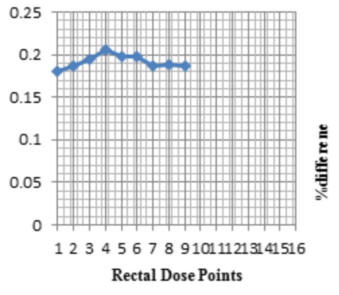

Figure 5: Percentage dose difference of computational and measured rectal doses in rando female pelvic phantom

DISCUSSION

The tissue heterogeneities have high potential to alter the delivered radiation dose and rectum is a hollow pipe filled with air and semi-solid faecal matter but the treatment planning system is used TG-43 formulism, assuming water equivalence to the rectum and adjacent tissues without considering the heterogeneities.

Uncertainties are found in planned and measured doses, mainly because of two reason, one is tissue heterogeneities which interact with photons by photoelectric effect, Compton scattering and pair production according to their atomic numbers and second is due to the positioning of the dosimeter. It is very important that the dosimeter is positioned at the same point as planned for rectal dosimetry.

The internal uncertainty of dose calculation based on the AAPM TG-43 formulism is approximately 10%[2] and reduction in dose value due to applicator is about 2% along the transverse plane of the source.[12]

Sakata et al. have measured doses in the rectum utilizing semicon ductor dosimeters during intracavitary brachytherapy procedures for treatment of gynecological cancer in 105 patients. The results indicate differences of up to 5% between planned and measured doses for 30.8% of the patients. The difference may reach 10% for 56% of the patients and up to 20% for 85% of the patients. For 15% of the patients the differences between planned and measured doses were higher than 20%.[13]

The results of this study are shown that the maximum percentage dose differences between computational and direct dose measurements are in the range of 15-21% which includes maximum 10% uncertainty due to TG-43 dose calculation formulism and 2% reduction due to applicator attenuation. The remaining uncertainties in percentage dose differences are due to positional in-accuracy of dosimeter which is kept minimal (within ±2%) and tissue heterogeneities in the pelvic region. The results of this study are close to the values reported in the literatures.[14,15] and further deep investigations are required.

The percentage dose differences indicate a need of re-evaluation of brachytherapy plans in order to complications that occur when the rectum is exposed to high radiation doses.

CONCLUSION

Heterogeneous female pelvic phantoms are very useful for direct dose measurements before execution of brachytherapy plans on the uterine cervix cancer patients. The plan can be evaluated and modified as needed for minimizing the rectal complications. MOSFET dosimeter is also very useful in rectal dosimetry due to their miniature size, easy to place and reproducibility in in-vivo dosimetry.

Funding: No funding sources
Conflict of interest: No
Ethical approval: Not required

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