

Rectal and Bladder Dose Measurements in the Intracavitary Applications of Cervical Cancer Treatment with HDR Afterloading System: Comparison of TPS Data with MOSFET Detector

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ABSTRACT

Background: Intracavitary brachytherapy plays a major role in management of cervical carcinoma. Assessment of dose received by OAR's therefore becomes crucial for the estimation of radiation toxicities in HDR brachytherapy.

Objective: Purpose of this study is to evaluate the role of in vivo dosimetry in HDR brachytherapy and to compare actual doses delivered to OAR's with those calculated during treatment planning.

Material and Methods: In this retrospective study, 50 patients of cervical carcinoma were treated by Microselectron HDR. Out of 50 patients, 26 were treated with a dose of 7 Gy and 24 with a dose of 9 Gy, prescribed to point A. Brachytherapy planning and evaluation of dose to bladder and rectum was done on TPS & in vivo dosimetry was performed using portable MOSFET.

Results: Calibration factors calculated for both dosimeters are almost equal and are 0.984 cGy/mV and 1.0895 cGy/mV. For bladder, dose deviation was found to be within $\pm 5\%$ in 28 patients, $\pm 5-10\%$ in 14 patients, $\pm 10-15\%$ in 4 patients. Deviation between TPS-calculated dose and dose measured by MOSFET for rectum was within $\pm 5\%$ in 31 patients, $\pm 5-10\%$ in 8 patients, and $\pm 10-15\%$ in 7 patients.

Conclusion: TPS calculated doses were slightly higher than that measured by MOSFET. The use of small size MOSFET dosimeter is an efficient method for accurately measuring doses in high-dose gradient fields typically seen in brachytherapy. Therefore, to reduce the risk of large errors in dose delivery, in vivo dosimetry can be done in addition to TPS computations.

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Keywords

MOSFET; ICRU; TPS; Brachytherapy; In Vivo Dosimetry; Radiation Dosimeters

Introduction

Cancer of the cervix uteri forms one third of diseases leading to death among woman worldwide. Intracavitary brachytherapy (ICBT) in combination with external beam radiotherapy (EBRT) forms an essential part of radiotherapy. However the main concern is how to interpret parameters correlated with organs at risk (OAR) that

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are pertinent to predict adverse results of brachytherapy [1, 2]. In brachytherapy, International Commission on Radiation Units and Measurements (ICRU) proposed dose reference points for bladder and rectum to predict clinically relevant endpoints and bring uniformity in dose reporting [3].

Evaluation of dose recorded by OAR in high-dose rate brachytherapy becomes necessary for the estimation of radiation toxicity. Additionally, the measurement of delivered dose during first treatment session may be utilized to plan subsequent dose fractions with corrective measures. Any source of error in delivery of dose can be detected by the quality assurance procedure in place.

Recently with the newer imaging technology, the protocols for prescribing and reporting doses have changed. Drastic changes are due to 3-D dose-volume estimations and reporting [4-6] in comparison with the point based on dose calculation formalism proposed by ICRU 38 [3, 7]. However, apart from reporting, a number of parameters show effects of estimated dose even in the era of 3-D planning.

In ICRT, *in vivo* dosimetry plays a vital role to predict doses for bladder and rectum and also helps to avoid misadministration of planned dose. Thermoluminescence dosimeters (TLDs) and semiconductor diodes were chosen for *in vivo* dosimetry by many groups [8-12]. These dosimeters are mainly used to measure dose for specific points that may not always represent the clinically relevant dose received by OAR and hence they require repetition of dose measurement at various points. MOSFET dosimeters are commonly used for *in vivo* measurement of dose in real time and also estimate point doses more accurate than other dosimeters due to the small sensitive volume.

The goal of the present study was to assess the role of *in vivo* dosimetry with mobile MOSFET detectors in HDR Brachytherapy and compare the dose received by organs at risk (using *in vivo* procedures) with calculated

dose using treatment planning system.

Material and Methods

In this retrospective study, 50 patients of cervical carcinoma were treated with Microselectron HDR. Out of 50 patients, 26 and 24 were treated with the dose of 7 and 9 Gy, respectively, prescribed to point A. Dose measurements with MOSFET were carried out for the first fraction of each patient using standard source loading pattern. All patients received high-dose rate ICRT along with EBRT during August 2017 and July 2018.

A combination of ovoid (half and full) and tandem angles (15°, 30° and 45°) of Fletcher-Suit model applicators (Nucletron) was used to suit patient's anatomy. Individualized gauze packing was done to immobilize the geometry of the applicators and distance bladder and rectum. Foley's catheter inserted into bladder was filled with 7 cc of diluted contrast and pulled down to be seated at bladder trigone. A rectal probe containing five radio opaque markers was inserted in the rectum to visualize on the radiograph set. Anterior-posterior (AP) and lateral radiographs were acquired on the X-ray machine for brachytherapy planning. Catheter reconstruction was done on the radiographs and also bladder and rectal points were identified with ICRU 38. Point A was defined on AP radiograph at 2 cm superior to the flange and 2 cm lateral from the axis of the intrauterine tandem. Patients were prescribed either the dose of 18 Gy delivered over 2 fractions or 21 Gy delivered over 3 fractions at point A. Dwell times were optimized to minimize dose to bladder and rectal points.

Further for *in vivo* dosimetry, portable MOSFET (metal oxide semiconductor field effect transistor) dosimetry system with two MOSFETs (TN – 502RD-H, SN: 33545 & 33546) of standard sensitivity and an electrometer TN RD 70W dose verification system (Team Best, Canada) were used for estimation of bladder and rectum dose. The MOSFET dosimeter is an electronic device that measures integrated

radiation dose. The small sensitive volume of 1 mm^2 with an active area of $0.2 \times 0.2 \text{ mm}$ located under a black epoxy bulb is used for dosimetry in steep dose gradients.

The Oncentra TPS version - 4.5.2 was used for brachytherapy planning and evaluation of dose to the bladder and rectum. The dose calculation algorithm used in this study is based on the formalism provided by Task Group-43 (TG 43, American Association of Physicists in Medicine). Treatment plans were optimized to keep bladder and rectal doses, below 80% of the dose prescribed to point A or to the extent possible. However, the dose to either bladder or rectum was greater than 80% of dose at point A in few cases.

A Siemens Somatom Emotion 16 slice CT scanner was used to acquire CT images of cylindrical phantom used for the calibration of MOSFET detectors. For calibration of MOSFET detectors, an acrylic cylindrical phantom with a hole at center (for source) and four equidistant holes from center located peripherally at 0.75 cm at 0° , 90° , 180° and 270° angles with MOSFET dosimeters in place was scanned by 5 mm slice thickness and the CT data was exported to TPS. Plans were generated by a single dwell position of Ir-192 source at the centre of cylindrical phantom with prescribed doses of 50 cGy, 100 cGy, 200 cGy, 300cGy, 500cGy, 700cGy and 900 cGy at 0.75 cm from the center. The dose-response curve was found to be linear for irradiation doses up to 9 Gy.

Results

The dose response curve for one MOSFET (TN – 502RD-H, SN: 33545) until the dose of 900cGy is shown in Figure 1. Two MOSFETs used in this study were calibrated and the dose response relationship is linear. The calibration factors calculated for both the dosimeters are almost 0.984 cGy/mV and 1.0895 cGy/mV, respectively.

The maximum absorbed dose measured using MOSFET detector & calculated by TPS

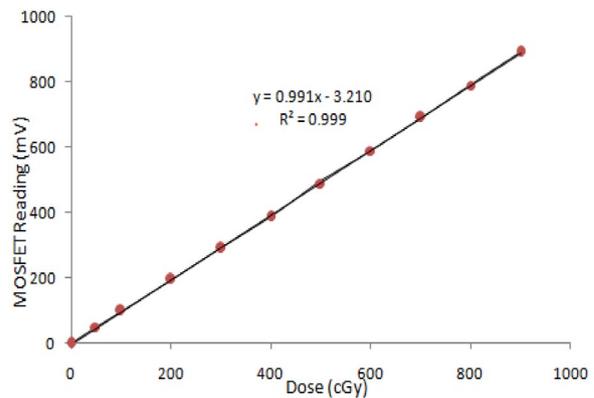


Figure 1: Calibration curve drawn between the prescribed dose and mobile MOSFET reading.

for bladder and rectum is shown in Figures 2 and 3 respectively. The mean dose estimated for the 50 patients, by TPS at the dose reference point placed in bladder is $6.13 \text{ Gy} \pm 1$ and the dose measured by MOSFET placed in bladder is recorded as $6.01 \text{ Gy} \pm 1$. For rectum, mean dose received by the TPS is $3.52 \text{ Gy} \pm 0.7$ whereas dose measured by the MOSFET placed in rectum is $3.40 \text{ Gy} \pm 0.7$. For bladder, dose deviation was found to be within $\pm 5\%$ in 28 patients, $\pm 5\text{-}10\%$ in 14 patients, $\pm 10\text{-}15\%$ in 4 patients. For four patients the dose deviation was over $\pm 15\%$ [Figure 4]. The deviation between the TPS-calculated dose and the dose measured by MOSFET for rectum was within

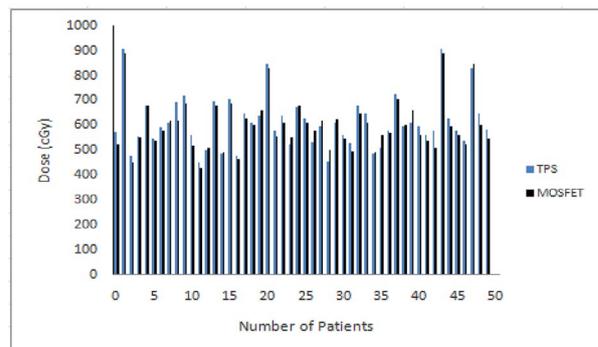


Figure 2: Comparison of bladder dose measured using a MOSFET Detector and calculated by TPS

$\pm 5\%$ in 31 patients, $\pm 5\text{--}10\%$ in 8 patients, and $\pm 10\text{--}15\%$ in 7 patients. Four patients recorded dose deviation exceeding $\pm 15\%$ [Figure 5].

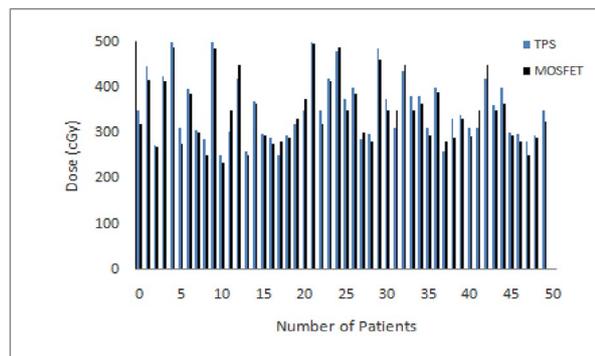


Figure 3: Comparison of rectal dose measured using a MOSFET Detector and calculated by TPS.

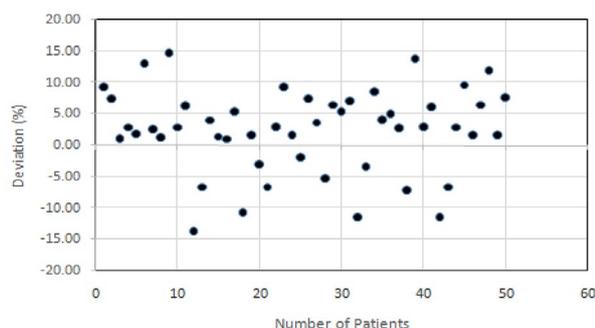


Figure 4: Figure shows the percentage deviation between the TPS dose and MOSFET dose for Bladder.

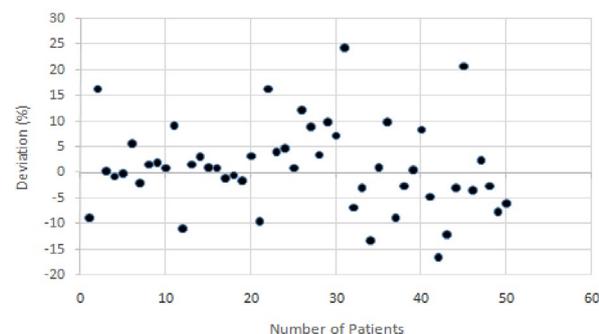


Figure 5: Figure shows the percentage deviation between the TPS dose and MOSFET dose for Rectum.

The data obtained from TPS and MOSFET was analyzed by the means of One - Way ANOVA using SPSS statistical software, version 20. No statistical significance was found between dose estimated by TPS and MOSFET for bladder and rectum, as $p\text{-value} > 0.05$.

Discussion

In the present study, we used MOSFET dosimeters for measurement of rectum and bladder dose according to ICRU 38. MOSFET dosimeters in external beam therapy are well documented; however, there are limited studies in brachytherapy applications. In intracavitary application, the point of dose measurement is placed in the high-dose gradient regions and therefore placement of the detector in the correct position is extremely important. In vivo dose measurements were compared with calculated data obtained from TPS. In general, the measured dose by the MOSFET detector is lower than the calculated doses at the ICRU reference points. This can be explained to a large extent with the steep dose gradient and positioning error of in vivo probes at the ICRU reference point. However, in spite of inaccuracy in the placement of MOSFET, the measured dose values can help prevent large errors from occurring during dose delivery.

Sha *et al.* [13] measured the rectum dose delivered in intracavitary application with 0.1 cm^3 ionization chamber probe and compared with ICRU reference point dose calculated by TPS. Their results for the 86 patients evaluated prospectively showed that the difference between the measured and TPS calculated dose was less than 5%, 5-10% and 10-14% in 52, 26 and 8 patients. Although, in our study, the difference between the MOSFET dose and TPS calculated dose was within $\pm 5\%$, $\pm 5\text{--}10\%$ and $\pm 10\text{--}15\%$ in 31, 8 and 7 patients, respectively. Four patients recorded dose deviation exceeding $\pm 15\%$.

Sakata *et al.* [14] evaluated the dose to rectum using a semiconductor detector in 105 patients treated with HDR brachytherapy. Their

results showed that the deviation between planned and measured doses is 5% for 30.8% of the cases. These differences reached up to 10% in 56% of the cases and up to 20% in 85% of the cases. They also observed that the deviation is more than 20% in 15% of the patients.

Waldhäusl et al. [15] considered 55 patients of gynecological cancer who were treated with HDR brachytherapy. They measured the dose using diodes. They observed that the difference between the measured dose and calculated dose is from -31% to +90%. These high differences were attributed to the uncertainty in the positioning of detector.

In this study, the described dosimetric procedure allows the evaluation of the dose delivered to the rectum and bladder as a consequence of the HDR brachytherapy for cervix cancer patients. The variation in the MOSFET response for the angles 0°, 90°, 180° and 270° was found to be $\pm 2\%$. This study closely is consistent with the study carried out by Ramaseshan et al. [16] using micro MOSFET where the angular dependence was found to be $\pm 2\%$ in a cylindrical phantom. Such type of procedure (online dosimetry) is very useful when the radiation dose is delivered for cervix cancer patients for comparing with the TPS delivered dose. With this approach, we can reduce the large errors between the planned and measured dose in order to protect the organ and minimize complications that may occur when rectum is exposed to high radiation doses.

Conclusion

In this study, bladder and rectum dose was estimated by MOSFET dosimeter and compared to that from TPS. In summary, the dose calculated by TPS was larger than the dose measured by MOSFET. The differences between measured and calculated doses seem to arise due to positional changes of anatomical organs and MOSFET during simulation and treatment delivery procedures. The use of a

small size MOSFET dosimeter is an effective tool for measuring accurate dose in high-dose gradient regions around brachytherapy sources, as in majority of cases the dose deviation was within $\pm 5\%$. Therefore, to reduce the risk of dose delivery errors in brachytherapy, in-vivo dosimetry should be performed as a quality assurance procedure.

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Conflict of Interest

None

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