RESEARCH ARTICLE

Analysis of *In-Vivo* Dose Measurement of Urethra Using Array MOSFET Detectors and TPS-Calculated Dose in High-Dose-Rate Interstitial Brachytherapy in Gynaecological Malignancies

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Abstract

   Objective: The urinary sub-structures, which lie in close proximity to the target, are often not contoured or evaluated during cervical cancer brachytherapy planning. This study aims to investigate the in vivo urethral dose during High-Dose-Rate Interstitial Brachytherapy applications using an array of Metal-Oxide-Semiconductor Field-Effect-Transistor detectors, and to compare the urethral dose recorded during brachytherapy planning with that calculated by the treatment planning system. **Methods:** Twenty patients with cancer of the cervix, vagina, or vault, from Stage IB to Stage IV, who were treated with external beam radiotherapy (EBRT) and interstitial brachytherapy, were included in the study. The high-risk clinical target volume and organs at risk, such as the urinary bladder, rectum, sigmoid colon, urethra, and periurethra, were delineated. The commercially available linear array MOSFET detector, with each detector and its reader module, was characterized and used in this study. The detector channel was inserted into the Foley's catheter until it reached the neck of the bladder. **Results:** The maximum and mean doses received by the urethra were 486.32 ± 105.88 cGy and 246.73 ± 101.43 cGy per fraction, respectively, for the prescription dose of 700 cGy/fraction. The maximum dose received by the periurethra per fraction of brachytherapy was 697.43 ± 165.26 cGy, and the cumulative dose, in terms of Equivalent Dose at 200 cGy (EQD_2) received by the periurethral region, including the EBRT dose, was found to be $13,406.1 \pm 2,909.17$ cGy. The urethral doses calculated by the Treatment Planning System (TPS) were compared with the doses measured by the detector per fraction of brachytherapy during treatment. **Conclusion:** The urethral doses calculated by the Treatment Planning System (TPS) were comparable to the doses measured by the MOSFET detector. Urethral dose measurement using an array of MOSFET detectors in patients treated with the Interstitial Brachytherapy (ISBT) technique proved its suitability and ease for measuring urethral dose. A good correlation was observed between the MOSFET-measured dose and the TPS-calculated dose, with a P-value > 0.05.

   Keywords: Interstitial Brachytherapy- In-vivo dosimetry- Array MOSFET- Urethra dose

Introduction

   Gynecological cancers are one of the commonest malignancies in India and hence a major health issue. It is the second most common cancer in women after breast cancer [1]. In the radical treatment of locally advanced cancer of the cervix, brachytherapy should be a component along with external beam radiation therapy (EBRT) [2].

   High dose rate (HDR) Interstitial brachytherapy (ISBT), is often used in the treatment of cervical and vaginal cancers when there is a residual disease in the lateral parametria post EBRT, narrow or stenosed vagina, distorted anatomy, or lower 1/3rd vagina is involved prior to starting of EBRT [3]. One of the major challenges in HDR interstitial brachytherapy lies in ensuring that the organs at risk (OAR) such as the rectum, bladder and urethra receive a safe radiation dose, thus avoiding detrimental effects on its functionality.

   The dose constraints for various dose fractionation schemes to OAR, such as the rectum, bladder and sigmoid colon were recommended by The Groupe Européen de Curiethérapie, the European Society for Radiotherapy and Oncology (GEC ESTRO) [4-7] and the American Brachytherapy Society (ABS) [8]. In normal practice, urinary sub-structures such as the urethra, other than the whole bladder are not routinely contoured and therefore,

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studies on dose constraints and dose-volume parameters for such organs are rarely available in the literature. The urethra is in close proximity to the target during ISBT, especially in cases of carcinoma cervix with involvement of anterior vaginal wall, vaginal and vault carcinomas [9].

The accurate assessment and control of radiation doses to critical OAR are of utmost importance to ensure therapeutic efficacy and minimize potential side effects. In the context of HDR interstitial brachytherapy, one of the critical OAR is the urethra, given its proximity to the tumor site. The delicate and sensitive nature demands meticulous attention to prevent complications. As a result, reliable and precise methods to measure the actual dose delivered to the urethra in real-time have become an area of research interest in the field of Radiation Oncology.

In order to assess the accuracy of the treatment planning system, (TPS) calculated dose and monitor dose to OAR; *in-vivo* dosimetry in radiation therapy is considered an essential QA tool. The International Commission on Radiation Units and Measurements (ICRU) report 24 states that an ultimate check of the actual treatment given can only be made by using *in-vivo* dosimetry [10, 11].

The present study aims to investigate the urethral dose during HDR ISBT applications using an array of Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) detectors for *in-vivo* dosimetry and to compare with the urethra dose recorded during brachytherapy planning by TPS.

Materials and Methods

This cross-sectional study was conducted between January to September 2023 among gynecological cancer patients, presenting to the Department of Radiation Oncology. Patients provided written informed consent before enrolment. No funding was availed for the study.

Study participants

20 patients with cancer of the cervix, vagina, or vault from stage IB to stage IV, who had received concurrent chemo radiation therapy with weekly cisplatin 40mg/m2 to a dose of 4500/4600cGy in 25/23 fractions to the primary tumor and the draining lymph nodes with 3DCRT technique and planned for ISBT were enrolled after consent.

Study methodology

The study was conducted as per the following steps.
1. Detector Calibration.
2. Brachytherapy procedure.
3. Brachytherapy planning computed tomography (CT) scanning.
4. Target and organs at risk delineation and optimization.
5. Brachytherapy implementation.

Detector Calibration
Detector

The commercially available linear array MOSFET detector with each detector having a silicon chip of dimension 1 mm × 1 mm with an active area of 0.2 mm × 0.2 mm, located under a black epoxy bulb (model TN-252LA5) along with mobile MOSFET reader module (Best Medical Systems, Canada) were used in this study. The array MOSFET has five detectors each placed two centimeters apart.

Calibration

The array MOSFET detectors were calibrated with Ir-192 in Gamma Med plus ix HDR machine to determine the calibration factors (CF) for each detector. The array was positioned with the bulb facing away from the source in a fabricated jig measuring 30 x 30 cm2 with provision for placing the source and detectors in the slab positioned in the same plane along with sufficient backscatter. This setup ensured each dosimeter on the array was equidistant and in the same orientation as the source. The jig along with the detector and backscatter material is scanned with a Philips Big Bore CT simulator for planning. A dose of 200cGy was delivered to each detector placed 2 cm away from the source tube located at the center of the jig. The dose was calculated using Brachyvision TPS. Dose was delivered via a source guide tube which is at the centre of the fabricated jig.

In order to find the angular dependence of the array MOSFET, a customized Perspex jig with provision for rotating the detector in four different angles such as 00, 900, 1800 and 2700 was made. The jig was immersed inside a water phantom for measurement (Figure 1). A dose of 200cGy was delivered to each detector. Readings were repeated for all four angles to find the angular dependency of the detector.

The linearity of the detectors was estimated with the original calibration setup by delivering the dose ranging from 50cGy to 600cGy. The acquired mean readings were normalized to 300cGy values for plotting the graph. To investigate the reproducibility of the array MOSFET detector, the detectors were irradiated in reference conditions three times with different doses ranging from 100cGy to 600cGy (Figure 1).

Brachytherapy procedure

The patients meeting the inclusion criteria, under aseptic precautions with spinal anesthesia, underwent Foley's catheterization of the urinary bladder using 16 French catheter to comfortably accommodate the array MOSFET detector channel. ISBT was performed using Syed-Neblett gynecological template. The number of needles to be inserted was decided based on the parametrial disease. Once the needles were inserted and the template was secured, the patient was moved out of the operation theatre for a brachytherapy planning CT simulation scan.

Brachytherapy planning computed tomography (CT) scanning

Brachytherapy planning CT simulation was performed using a Philips wide bore CT simulator. 10cc of normal saline was infused into the urinary bladder to maintain uniformity in bladder volume. The array MOSFET detector channel was inserted inside the Foley's catheter and pushed to the neck of the bladder (catheter bulb).
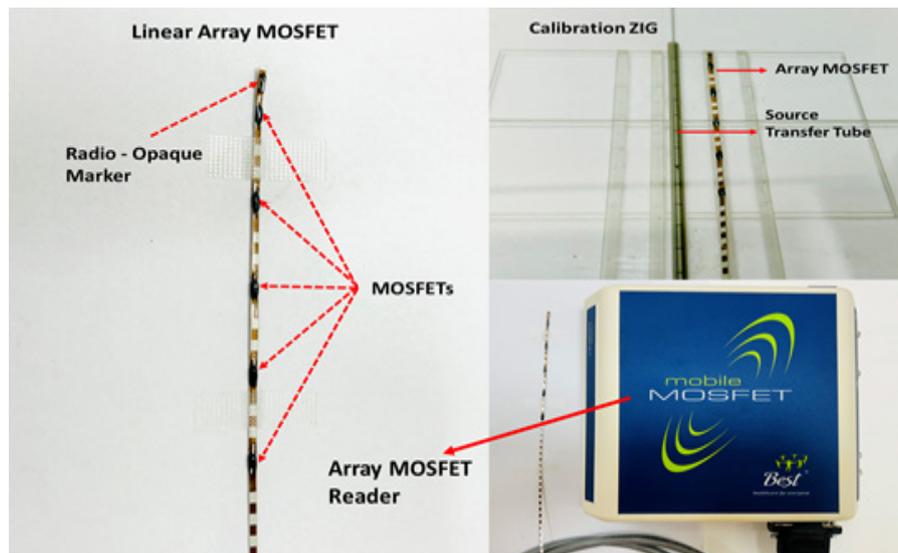
Figure 1. Illustration of Linear Array MOSFET and the Calibration jig

Non-contrast plain CT scan was performed from 1st sacral vertebra to mid-thigh with a 2mm slice thickness.

Target and organs at risk delineation and optimization

The high-risk clinical target volume (HRCTV) was delineated based on examination under anaesthesia and pre brachytherapy MRI volume in accordance to The Groupe Européen de Curiethérapie (GEC), the European Society for Radiotherapy and Oncology (ESTRO) guidelines, along with the organs at risk urinary bladder, rectum, sigmoid colon and urethra on the simulation CT scan in Eclipse Brachyvision system by Varian Medical System, Palo Alto, USA. A dose of 700cGy per fraction to a total dose of 2100cGy over 3 fractions was prescribed to the HRCTV. Once a satisfactory plan was generated, it was approved and the plan was transferred to the treatment machine for treatment execution. The dose received by 90% (D90) of the HRCTV, 2cc of the urinary bladder, periurethra, rectum sigmoid colon and urethral dose were documented from TPS.

Brachytherapy implementation

Treatment was delivered using Gamma Med Plus (Varian Medical System, Palo Alto, USA) HDR brachytherapy unit housing Ir-192 radioactive source with a maximum of 10Ci activity. After connecting all the implant needles to the transfer tube of the HDR machine, the detector was connected to the mobile MOSFET reader module for recording the urethral dose (Figure 2). Once treatment was completed the detector was removed from the Foley's catheter and sterilized with glutaraldehyde solution.

in-vivo measurement

The detector channel was pushed until the neck of the bladder (catheter bulb). The array MOSFET detector channel was inserted inside the Foley catheter at the time of the simulation. CT images were obtained with a 2 mm slice thickness for planning. The detectors were identified and marked as a point of interest labeling them as M1, M2, M3, M4 and M5 in the TPS. After the delineation of the target and OARs such as the rectum, bladder, urethra, periurethra and sigmoid, plans were generated for the HR CTV for the prescribed dose of 700cGy in the TPS. After the plan evaluation and approval process, the patient was shifted to the treatment room. Once all the needles are connected to the transfer tube of the HDR machine, the detector was connected to the mobile MOSFET reader module for recording the urethral dose. The *in-vivo* dose measured by the array of MOSFET detectors at the bladder neck, proximal and distal end of the urethra was documented. The dose distribution indicating the positioning of the MOSFET detector is shown in Figure 2.

Statistics

All the categorical data like age, stage of the disease and EBRT dose were documented in terms of percentages and proportions. Contiguous data like volumes and dose received by the organs expressed in terms of means and standard deviations. Paired t-test was used to compare the difference in means of dose calculated in TPS to urethra to the dose received by urethra at the time of treatment using the detectors and a Pvalue of < 0.05 was considered statistically significant.

Results

Calibration

Individual Calibration factor (CF) was determined for each detector in the array. The difference in CF was small for detectors on the same array but varied significantly between the two arrays used in the study. The CF with the first set of arrays was observed with a maximum of 2.44% deviation from the prescribed dose of 200 cGy. The CF for the second set of array detectors varied with a maximum of 2.96% with the prescribed dose.

The sensitivity of each MOSFET in the array was determined which ranged from 0.80 and 0.87 mV/cGy (n=3). These results are consistent with the values provided by the manufacturer for a random batch of

MOSFET arrays. The response of the detector was linear for dose values ranging from 50 cGy to 600 cGy with R values of 0.999 and 0.995 for the first and second array detector sets. A graphical representation of the linearity for one set of array MOSFET is shown in Figure 3. The angular dependence measurement of the detector response showed the maximum difference with 2700 positioning of the detector bulb with - 3.76% with the prescribed dose of 200cGy. The results with the reproducibility check showed an acceptable deviation of up to 1.3% (n=3) for the dose ranging from 100 to 600cGy with increments of 100cGy.

Treatment

A total of 20 patients meeting the inclusion criteria were enrolled in the study. The basic characteristics of patients enrolled in the study are enumerated in Table 1. The mean length of the urethra was 3.78 cm ± 0.41 and the mean volume of the urethra was 1.25 cc ± 0.39.

The TPS calculation showed that the mean D90% of HRCTV as 728.93± 65.23 cGy per fraction. The 2cc dose to bladder, rectum and sigmoid was 448.93±92.86 cGy, 426.28 ± 61.49 cGy and 199.02±105.32 cGy per fraction

Table 1. Baseline Characteristics of the Cases

Parameter	Baseline characteristics	n (%)
Sub-site of cancer	Cervix	16
	Vault	4
Stages	Stage- II B	4 (20%)
	Stage-III	15 (75%)
	Stage-IV	1 (5%)
The volume of urethra (Means ± SD cc)	1.245 ± 0.39	
Length of urethra (Means ± SD cm)	3.378 ±0.41	

respectively. The maximum dose received by the urethra and periurethra was 486.32 ± 105.88 cGy and 697.43± 165.26 cGy per fraction respectively. The mean dose received by 1cc of urethra was 246.73 ± 101.43 cGy per fraction. The cumulative dose in terms of EQD_2 values for HRCTV (90%) were found to be 7740.90± 486.99 cGy. For the bladder, rectum and sigmoid the EQD2 values were 6638.1 ± 666.45 cGy, 6441.10± 474.21 cGy
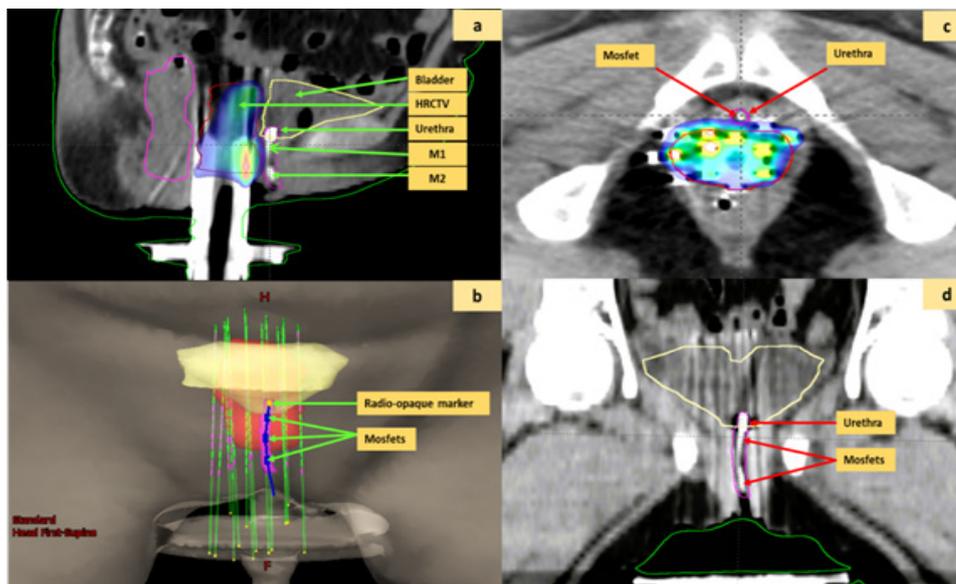

Figure 2. The Dose Distribution of ISBT Treatment Showing a) HRCTV and OARs b) 3D illustration of ISBT implant indicating the MOSFET detectors inserted in the urethra c) Dose distribution in transverse view showing the urethra and implant volume d) Coronal view of the implant section showing the urethra and MOSFET.

Table 2. Total Dose Received by Urethra in Terms of EQD_2

Dose (TPS)	D_{max} (Mean ±SD)cGy	D_{mean} (Mean ±SD)cGy	D_{1cc} (Mean ±SD)cGy	$D_{0.1cc}$ (Mean ± SD)cGy
Brachytherapy dose per fraction	486.32± 105.88	302.49 ± 103.10	246.73± 101.43	407.01± 93.63
EBRT+ Brachytherapy (EQD_2)	6327.46 ±675.44	5480.97± 510.75	5376 ± 403.10	5838 ± 362.78

Table 3. Total Dose Received by Periurethral in Terms of EQD_2

Dose (TPS)	D_{max} (Mean ±SD)cGy	D_{mean} (Mean ±SD)cGy	D_{1cc} (Mean ±SD)cGy	$D_{0.1cc}$ (Mean ± SD)cGy
Brachytherapy dose per fraction	697.43± 165.26	297.41 ± 110.31	420.82 ± 119.44	588.145 ± 180.52
EBRT+ Brachytherapy (EQD_2)	13406.1± 2909.17	6264.3 ± 1361.93	8466.5± 1838.49	11574 ± 2514.39

Table 4. EQD$_2$ Values Derived from TPS for HRCTV, Bladder, Rectum and Sigmoid

Dose (TPS)	HRCTV D90% (Mean ± SD) cGy	Bladder 2cc (Mean ± SD) cGy	Rectum 2cc (Mean ± SD) cGy	Sigmoid 2cc (Mean ± SD) cGy
Brachytherapy dose per fraction	728.93± 65.24	448.93± 92.86	426.28 ± 61.49	199.02 ± 105.32
EBRT+ Brachytherapy (EQD$_2$)	7740.90 ± 486.99	6638.1 ± 666.45	6441.1± 474.21	5231.75± 560.68

Table 5. Comparison of TPS Calculated Dose versus Measured Dose in Urethra

Site of urethra	Dose as per TPS (Means±SD)cGy	The dose recorded by the detector (Means±SD) cGy	P-value	t-value
Bladder neck	365.5 ± 79.7	359.5 ± 74.2	0.215	1.3
Proximal	349 ± 67	344.7 ± 63.2	0.214	1.3
Distal	179.4 ± 54.8	178.8 ± 58.3	0.793	0.3

and 5231.75 ± 560.68 cGy respectively. The cumulative EQD$_2$ to urethra and periurethra was 6327.46 ±675.44 cGy and 13406.1± 2909.17 cGy respectively. The EQD$_2$ dose received by 1cc of the urethra and periurethra was 5376 ± 403.10 cGy and 8466.5± 1838.49 cGy respectively (Table 2). The calculated EQD$_2$ dose from the TPS generated values for HRCTV (D90%), bladder, rectum and sigmoid is shown in Table 4.

The doses calculated as per the TPS to the urethra were compared to the dose received by the urethra as recorded by the detector per fraction of brachytherapy during treatment (Table 5). The Paired t-test showed a p-value of 0.215 for the bladder neck, 0.214 for the proximal urethra and 0.793 for the distal urethra respectively with p-values>0.05 which indicates that the readings obtained are statistically insignificant. Hence, the implying dose calculated by TPS and the dose recorded by the detector were nearly identical.

Discussion

The dose measurements in the vicinity of the high activity source are challenging due to extremely steep dose gradients associated with brachytherapy [12]. HDR treatments usually proceed very quickly and it can be difficult to verify treatments in this short time. In the literature, it is found that MOSFET detectors are very suitable for routine phantom measurements in HDR brachytherapy [13-16]; they have several characteristics that make them suitable for brachytherapy including small size, dose rate independence, and instant readout, requirement of low power, detector irradiation without cables and negligible attenuation of radiation [17].

The use of MOSFET detectors offers the advantages of real-time dose measurement, spatial resolution and minimal interference with the radiation delivery process, making them ideal candidates for assessing urethral dose during interstitial brachytherapy. To achieve this objective, a cohort of patients undergoing HDR interstitial brachytherapy for various treatments of carcinoma cervix were subjected to *in-vivo* dose measurements using an array of MOSFET detectors.

Amsbaugh et al. [18], studied the toxicity in 73 patients receiving interstitial brachytherapy (ISBT) for gynecological cancers. ISBT was performed using both high-dose rate and low-dose-rate Ir-192 sources (27 low-dose rate and 46 high-dose rate). The authors reported that the dose of 2037.00 cGy received to 0.1cc of the
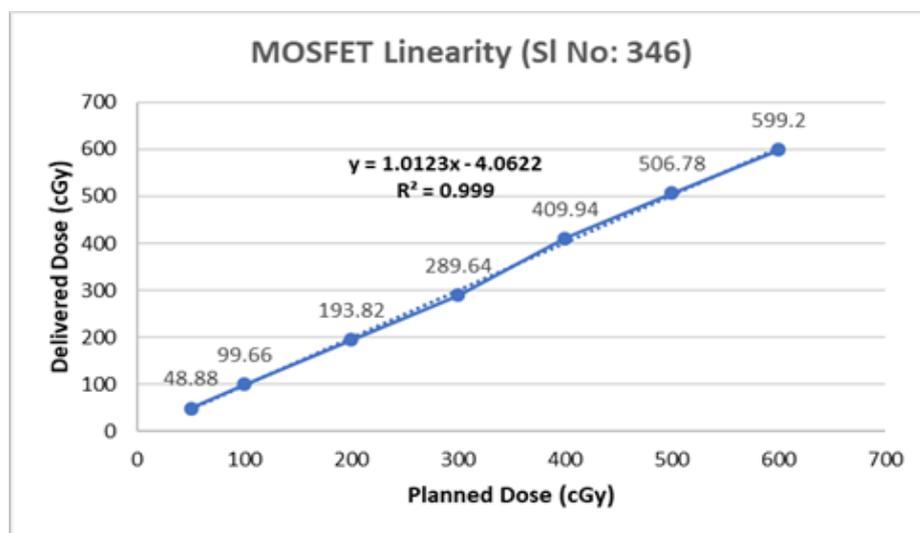

Figure 3. Linearity Graph of Delivered Dose versus Planned Dose

urethra predicted for the development of Grade 3 urinary toxicity for a median follow-up of 12 months. The author has concluded that the dose to a small urethral volume may be the most significant predictor of urinary toxicity in patients receiving ISBT in gynecological cancer. In our study, we observed the urethral dose for 0.1cc volume as 1776± 6.3 cGy and further clinical follow up would reveal the toxicity profile.

Gurp et al. [19], performed *in-vivo* dosimetry using MOSFET dosimeters in 17 patients to evaluate the dose in the urethra after a permanent prostate implantation procedure during brachytherapy with I-125 seeds. Patient measurements were performed with a MOSFET array in the urinary catheter immediately after the implantation procedure. The TPS results were compared with the *in-vivo* dose values measured with MOSFET dosimeters. In the high-dose region (> 100 Gy), calculated and measured dose values agreed within 1.7% ± 10.7% (1 SD). In the low-dose region outside the prostate (< 100 Gy) the agreement was reported as 1.5% ± 7.2% (1 SD). In our study, it was observed that the bladder neck dose of calculated and measured as 3.65 ±0.79Gy and 3.59±0.74 Gy respectively. The deviation of the two readings was found to be 1.35 % ± 4.23% which is similar. Similarly, the proximal and distal end of the urethra was 0.94 % ± 4.36% and 0.72% ± 4.42% respectively between the calculated and measured values.

Haughey et al. [20], assessed the suitability of array MOSFET detectors as *in-vivo* dosimeters to measure rectal dose in high dose rate brachytherapy treatments. Two sites were investigated for *in-vivo* measurements, transperineal needle implants for prostate cancer and intracavitary applicator for cervical cancer. Measured rectal doses during treatment were compared with point dose measurements predicted by the TPS. *in-vivo* results for prostate patients found only 33% of measured doses agreed with the TPS within ±10%. For cervix cases, 42% of measured doses agreed with the TPS within ±10%, however of those not agreeing, variations of up to 70% were observed. One of the most limiting factors in this study was found to be the inability to prevent the MOSFET from moving internally between the time of CT and treatment. Due to the many uncertainties associated with MOSFETs including calibration drift, angular dependence and the inability to know their exact position at the time of treatment, the authors concluded that the MOSFETs are unsuitable for *in-vivo* dosimetry in rectum for HDR brachytherapy. In our study the array MOSFET was inserted in the Foleys catheter and secured with wedge shape stopper along with reference marking made on the posterior end of the draining channel for each patient. The tip of the detector was positioned at the level of inflated bulb of the Foleys catheter and was confirmed with the CT simulation.

Our earlier Institutional study by Radhakrishna et al. [9], estimated the dose-volume parameters of the female urethra during high-dose-rate ISBT in 24 patients treated for gynecological malignances. The authors have contoured urethra and periurethral regions. The mean volume, D_{max}, D_{mean}, D_{2cc}, D_{1cc}, $D_{0.5cc}$, $D_{0.2cc}$ and $D_{0.1cc}$ were recorded. Mean doses received by urethra per BT fraction were D_{max} = 423 ±132 cGy, D_{mean} = 271 ±101 cGy, $D_{0.2cc}$= 331 ±107cGy and $D_{0.1cc}$ = 354 ±109 cGy. The study concluded by stating that the female urethra receives significant doses during ISBT for gynecological malignancies, especially when the anterior vaginal wall is within the target volume. In the present study, the mean doses received by urethra per BT fraction for D_{max} = 486 ±105 cGy, D_{mean} = 302 ±103 cGy, $D_{0.2cc}$= 380 ±94 cGy and D0.1cc= 407 ±93 cGy. Similarly, the mean doses received by periurethra per BT fraction for D_{mean}, D_{1cc}, $D_{0.5cc}$, $D_{0.2cc}$ and $D_{0.1cc}$ were 297 ±110 cGy, 420 ±119 cGy, 473 ±134 cGy, 541 ±157 cGy and 588 ±180 cGy respectively. The difference in the values reported by Radhakrishna et al. [9], and our study could be due to the difference in the prescription dose of BT which was 6 Gy and 6.5 Gy in 4 fractions.

Hathout et al. [21], studied anatomic structure predictive for acute (AUT) and late (LUT) urinary toxicity in patients with prostate cancer treated with low-dose-rate brachytherapy (LDR) with or without EBRT. Nine hundred and twenty seven patients with prostate cancer underwent LDR brachytherapy using I-125 (n=753) or Pd-103 (n=174) as definitive treatment (n=478) and as a boost (n=449) following EBRT (median dose5040cGy). Structures contoured on Day 0 post implant CT scan included prostate, urethra, bladder and the bladder neck, defined as 5 mm around the urethra between the catheter balloon and the prostatic urethra. AUT and LUT were assessed. Clinical and dosimetric factors associated with AUT and LUT were analyzed, Grade ≥2 AUT and grade ≥2 LUT occurred in 56% and 20% patients respectively. No grade 4 toxicities were observed. Bladder neck D_{2cc} retained a significant association with AUT as 2cc bladder neck was represented as maximum dose, urethra (D20% > 130%), bladder neck (D_{2cc} > 50%) dose was shown to have the strongest prognostic power for AUT (AUC, 0.697; P < 0.001) and LUT. The study concluded that the bladder neck D_{2cc} > 50% was the strongest predictor for grade ≥ 2 AUT and LUT in patients treated with LDR brachytherapy. These data support the inclusion of bladder neck constraints into brachytherapy planning to decrease urinary toxicity. In our study, $D_{0.1cc}$ has been considered as maximum dose of bladder neck and the observed values for the same are 365.5± 79.7 cGy and 359.5 ± 74.2 cGy for the calculated and measured respectively. The toxicity will be assessed during the follow-up of these patients.

Groen et al. [22], in their The FLAME trial showed that by adding a focal boost to conventional fractionated EBRT in the treatment of localized prostate cancer, the five-year biochemical disease-free survival increased, without significantly increasing toxicity. They aimed to investigate the association between radiation dose to the bladder and urethra and genitourinary (GU) toxicity grade 2 in the entire cohort. The dose-effect relations of the urethra and bladder dose separately and GU toxicity of grade 2 up to five years after treatment were assessed. The median planned dose to the D_{2cc} of the bladder and the $D_{0.1cc}$ of the urethra were 7500 cGy and 8000 cGy, respectively. Additionally, associations between the dose to the urethra and bladder and the sub-domain's urinary frequency, urinary retention and urinary incontinence were

observed by the authors. The odds ratios for the urethra $D_{0.1cc}$ for developing GU toxicity grade 2 were 1.13 and 1.12 per increase of 100 cGy.

The study concludes by stating that further increasing the dose to the bladder and urethra will result in a significant increase in GU toxicity following EBRT. The grade ≥ 2 GU toxicities irrespective of treatment arms (7700 cGy/35 # and 9500 cGy/35# - SIB) was 8% of patients out of 571, 1% had Grade 3 toxicities with a median follow-up of 72 months. In our study, the maximum EQD_2 dose observed was 6327 ± 670 cGy hence long term clinical follow up is essential to establish the toxicity to be less than what has been observed by Groen et al. [22]

In conclusion, the urethral dose measurement using an array MOSFET in patients treated with ISBT technique proved its suitability and ease in the measurement of urethral dose. Additionally, the array MOSFET can also be used to find the bladder neck dose, mean dose and maximum dose simultaneously in a single attempt. Good correlation exists between the MOSFET measured dose and the TPS with P value >0.05. The study emphasizes the importance of recording urethral dose in the plan evaluation process to avoid any complication to the urethra which is normally overlooked during the decision-making process.

Author Contribution Statement

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sushma N, Tanvir Pasha C R, Nirupama Y S, ShanmukhappaKaginelli, Sathiyaraj P, Nikhila K R, Manjula M V and Ganesh K.M. All authors read and approved the final manuscript.

Acknowledgements

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