Study of positional dependence of dose to bladder, pelvic wall and rectal points in High-Dose-Rate Brachytherapy in cervical cancer patients

Anil Kumar Talluri, Krishnam Raju Alluri, Deleep Kumar Gudipudi, Shabbir Ahamed, Madhusudhana M. Sresty, Aparna Yarrama Reddy[1]

Department of Radiation Oncology, Basavatarakam Indo American Cancer Hospital and Research Institute, Hyderabad, [1]Department of Physics, Jawaharlal Nehru Technological University, Kukatpally, Hyderabad, Andhra Pradesh, India

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ABSTRACT

The objective of the study is to examine the variation in doses to, Bladder, pelvic wall and Rectal Points when a patient is simulated in Supine (S Position) and Lithotomy M shaped positions (LM Position), respectively as part of Intracavitary Brachytherapy in Cervical Cancer patients. Patients (n = 19) were simulated and orthogonal images were taken in S Position and LM Positions on a physical simulator. Digital orthogonal X-ray images were transferred to Brachyvision Treatment Planning System via Dicom to generate treatment plans. Radio opaque dye of 7 ml was injected into the Foley bulb for identification and digitization of International Commission on Radiological Units and Measurements (ICRU) Bladder point. Pelvic side wall points were marked in accordance with ICRU 38 recommendations. A Rectal tube containing dummy source marker wire was used to identify Rectal Point. Students't-test was used to analyze the results. Doses in LM Position were lower and statistically significant when compared to S Position for ICRU Bladder Point, pelvic walls and Rectal Point. It was observed that movement of applicator could be the reason for the variations in doses between the two positions. Bladder, pelvic wall and rectal points systematically registered lower doses in LM Position as compared to S Position.

Key words: Bladder, lithotomy, rectum, supine

Introduction

Cancer of the Cervix is preventable, yet approximately 493,100 new cases and more than 273,000 deaths occur each year among women worldwide.[1] Cancer, known medically as a malignant neoplasm, is a broad group of various diseases, all involving unregulated cell growth. In cancer, cells divide and grow uncontrollably, forming malignant tumors, and invade nearby parts of the body. The cancer may also spread to more distant parts of the body through the lymphatic system or bloodstream. Among females the most common cancer sites are Cervix and Breast. Carcinoma of the cervix is radiosensitive and radiation is used for all stages of cancer and where surgery is not possible. Cancer of the uterine cervix has a high incidence rate among women in India. There are approximately 130,000 new cases of cervical cancer in India per year and the disease is reported to be responsible for almost 20 percent of all female deaths.[1] Most of the radical cases are treated by combination of External beam therapy and Brachytherapy.

Low-Dose-Rate (LDR) brachytherapy has been clinically proved in controlling the tumor with acceptable late morbidity.[2-7] High-Dose-Rate (HDR) brachytherapy overcomes the disadvantages of LDR brachytherapy with the added advantages of patient throughput, reduced treatment time and flexibility in dose optimization. Although the dose is delivered at a higher rate than in LDR brachytherapy, the possible late effects can be reduced by adopting low fraction size and multiple fractions with adequate time gap between fractions. All fractions require careful individualized planning due to the geometrical variation of applicators arising from the differences in the

Address for correspondence:
Mr. Anil Kumar Talluri,
Department of Radiation Oncology, Basavatarakam Indo American Cancer Hospital and Research Institute, Road No 14, Banjara Hills, Hyderabad - 500 034, Andhra Pradesh, India.
E-mail: mailfortalluri@yahoo.co.in

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anatomy of the patient, variations in packing and position of the patient, keeping the rectal and bladder doses within the acceptable limits.[8-16] The applicator, inserted into the patients' uterine canal and vaginal cavity varies with the anatomical position of the patient. Due to this there is a variation in doses to various anatomical points. Orthogonal film based planning is the standard practice recommended by the American Brachytherapy Society[17] and this is being followed in most of the centers in India.

Materials and Methods

Our center treats nearly 50 patients per week with intracavitary radiation for gynecological malignancies which includes cervical cancer, vagina cancer and cancer of the vault, along with external beam radiation therapy. In this study, number of patients was limited to nineteen due to workload. Supine position (S Position) [Figure 1] is the standard position adopted in this institute to generate and deliver treatment plans. In the present study another position, Lithotomy M shape Position (LM Position) [Figure 2], was added to make a comparison study. Sometimes patients feel more comfortable in LM Position. This study was done adopting LM Position along with the standard S Position. Our center does not practice with applicator stabilizer.

Nineteen patients with Carcinoma of the Cervix of grade II and III, aged between 30 to 60 years were selected for this study. Two plans for each patient in two anatomical positions were created by treating each plan as independent of the other. All patients were imaged simultaneously in two positions, S Position and LM Position, on Acuity physical simulator (Varian, Palo Alto, CA, USA) to get orthogonal digital X-ray images [Figures 3 and 4] at gantry angles 0° and 90° after insertion of Henschke applicator (Mick Radio-Nuclear Instruments, Inc., NY, USA) and to confirm the adequacy of position and orientation of the applicator. After imaging, patient was shifted to HDR brachytherapy (Varisource iX, Palo Alto, CA, USA) room for treatment, which is not an integral part of operation theatre, and digital images [Figures 3 and 4] were sent via Dicom to Brachyvision Treatment Planning System (TPS) Version 7.3 (Varian, Palo Alto, CA, USA) through Varian ARIA (Varian, Palo Alto, CA, USA) network.

Henschke applicator with different tandem lengths and ovoid diameters were employed depending on the patients' anatomy. Tandem length varies between 4 to 6 cm and ovoids diameter varies from 2-3 cm. Doses ranging from 600 cGy-700 cGy were prescribed to Point A. Brachyvision TPS was used to generate treatment plans. Dose was

Figure 1: Patient in Supine Position

Figure 2: Patient in Lithotomy M Shape Position

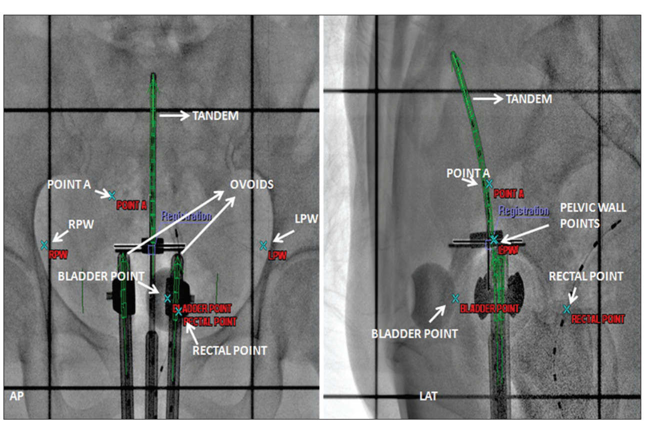

Figure 3: Orthogonal digital X- ray image in Supine position

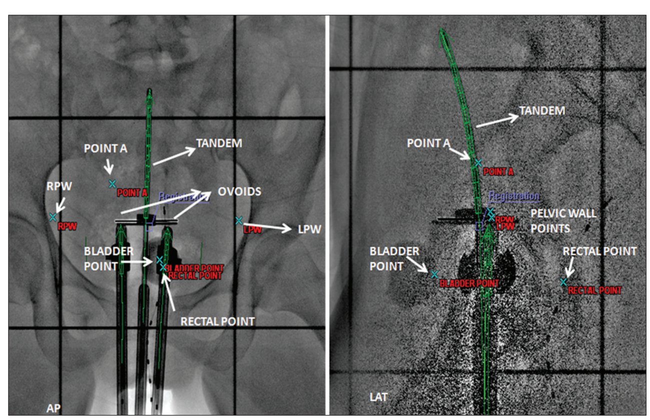

Figure 4: Orthogonal digital X- ray image in Lithotomy M Shape position

optimized to Point A and to reference lines placed at 0.5 cm apart from the surface of ovoids. The dose distribution [Figures 5 and 6] and source loading pattern was the same for both the positions. Both the plans were generated with first time insertion of applicator in either position.

Dose reference points, Bladder, Pelvic wall and Rectal Points were identified for analysis. The ICRU Bladder and pelvic wall points were identified according to ICRU 38[20] recommendations. Radio opaque dye, Omnipaque (GE Healthcare, UK) of 7cc volume having a density of 350 mg I/ml was injected to inflate the Foley bulb to identify bladder point. It was located at the centre of Foley bulb on AP radiogram and on the line, passing through the centre of bulb, at the posterior surface of the balloon on LT LAT radiogram. The pelvic wall reference points, Right Pelvic Wall (RPW) and Left Pelvic Wall (LPW), can be visualized on AP and LAT radiogram. On an AP radiogram, the pelvic wall reference point is intersected by the following two lines: A horizontal line tangential to the highest point of the acetabulum, a vertical line tangential to the inner aspect of the acetabulum. On a lateral radiogram, the highest points of the right and left acetabulum, in the cranio-caudal direction, are joined and the lateral projection of the pelvic-wall reference points are located at the mid-distance of these points. A Rectal tube containing dummy source marker wire was used to identify the rectal point. It was identified at the intersection of rectal marker and a line joining the centers of the right and left femoral heads on Anterior Posterior (AP) radiogram and on the rectal marker wire at the same level in the Left Lateral (LT LAT) radiogram. Student's *t*-test was used to analyze the results.

Results

Considerable differences occurred between the doses at the ICRU Bladder point when measured in Supine position and Lithotomy M positions [Table 1]. Results were expressed as a percentage of S Position. The range of dose differences was large with a minimum of −0.15% and a maximum −15.15% with a mean of −7.0% (P = 0.00001). Four of nineteen patients exhibited difference of over −5% and in seven of them the difference amounted to more than −10%.

Pelvic wall points registered lower doses in lithotomy [Table 2]. For RPW the range of dose differences from 7.4% to −19.8% and mean of −8.1% (P = 0.0004) was observed. Similar results were observed for LPW with the dose difference ranging from 5.9% to −16.3% with a mean dose of −8.7% (P = 0.00003).

Rectal point dose was analyzed and observed that the LM Position registered, a mean dose of −5.0% (P = 0.0043) ranging from 7.1% to −15.5% as compared to Supine position [Table 1]. Three patients out of 12 exhibited differences ranging from −5% to −10% and six of them registered more than −10%.

LM Position registered systematically lower doses compared to S Position for bladder, pelvic wall and rectal Points. The mean difference of −7.0% for ICRU bladder, −8.1% and −8.7% for right and left pelvic wall points and −5.0% for rectal point cannot be explained by inaccuracies in TPS dose measurements, but suggests a true difference between doses in two positions.

Discussion

In the present study with nineteen patients, two plans for each patient corresponding to S and LM positions were created. Applicator is a rigid device, made of stainless steel. It is inserted into the patients' vaginal and uterine cavities, with sufficient Gauge packing around applicator. Gauge pack serves two purposes; it pushes the rectum and bladder away from the applicator and produces enough immobilization to the applicator *in situ*. Gauze packing is one of the factors affecting the dose to rectum and

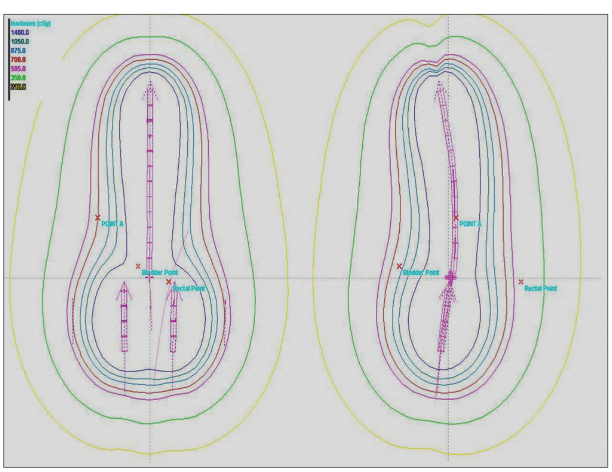

Figure 5: Dose distribution in Supine position

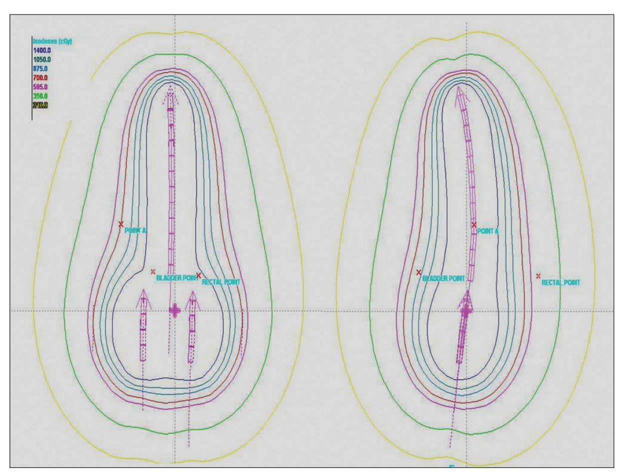

Figure 6: Dose distribution in Lithotomy M Shape position

Table 1: Individual differences in doses between TPS values in S Position and LM Positions as percentage of values obtained with the patient in S Position for Bladder and rectal points

Rectum				*Bladder*			
Supine cGy	Lithotomy cGy	% difference	Patient index	Supine cGy	Lithotomy cGy	% difference	POINT A cGy
481	515	7.1	1	855	844	−1.3	700
445	453	1.8	2	995	993	−0.2	700
536	543	1.2	3	765	713	−6.8	700
536	460	−14.2	4	812	754	−7.1	700
498	467	−6.2	5	805	797	−1.0	700
367	360	−1.9	6	325	322	−0.9	700
449	400	−10.9	7	467	456	−2.3	600
635	550	−13.4	8	1117	1088	−2.6	700
652	556	−14.7	9	1156	1135	−1.8	700
580	574	−1.0	10	944	930	−1.6	700
621	525	−15.5	11	477	405	−15.1	600
408	350	−14.2	12	176	149	−15.1	700
478	500	4.6	13	511	458	−10.4	600
480	444	−7.5	14	912	845	−7.4	700
388	400	3.1	15	743	646	−13.1	700
483	483	0.1	16	748	642	−14.2	700
977	900	−7.8	17	1216	1111	−8.6	700
320	340	6.2	18	469	411	−12.5	700
327	290	−11.3	19	781	682	−12.8	700

Table 2: Individual differences in doses between TPS values in S Position and LM Positions as percentage of values obtained with the patient in S Position for pelvic wall points

RPW				*LPW*			
Supine cGy	Lithotomy cGy	% difference	Patient index	Supine cGy	Lithotomy cGy	% difference	POINT A cGy
216	187	−13.5	1	223	211	−5.4	700
218	230	5.5	2	227	240	5.9	700
184	148	−19.5	3	194	166	−14.4	700
198	183	−7.4	4	193	167	−13.7	700
139	111	−19.8	5	164	150	−8.2	700
150	130	−13.4	6	102	95	−6.9	700
82	88	7.4	7	139	130	−6.3	600
145	119	−17.8	8	130	119	−8.7	700
157	132	−16.3	9	144	120	−16.3	700
176	167	−5.3	10	196	178	−9.6	700
157	165	5.4	11	146	125	−14.0	600
172	145	−15.5	12	232	220	−5.0	700
134	130	−3.1	13	149	130	−12.5	600
250	231	−7.6	14	221	213	−3.7	700
117	107	−8.7	15	131	118	−9.3	700
107	98	−8.5	16	175	156	−10.7	700
177	183	3.6	17	142	128	−9.5	700
263	218	−17.0	18	237	204	−13.9	700
178	172	−3.2	19	111	107	−3.5	700

bladder.[8] In addition to packing the other factor is the position of the patient.[18,19] Hoskin PJ[22] *et al.*, discussed the influence of applicator angle on Dosimetry in vaginal vault brachytherapy. In S Position which is a normal resting position the soft tissues in the pelvis are relaxed. However the change in patients' position to LM Position, results in the exertion of pressure by the lateral tissues of pelvis which leads to spatial rearrangement of Rectum, Bladder and Applicator. These movements are the reason for the observed variation in doses to Rectum and Bladder. It is observed that applicator moved on an average by 0.35 cm inferiorly in LM position compared to supine position with respect to rectal point which is in turn related to fixed bony landmark.

It is the reason to observe lower doses at defined rectal point but not the entire rectal wall. However the same is also the reason for the increase in dose to rectal point as it depends on relative position of rectal point and ovoids. Doses at two other points, superior rectal (SRP) and inferior rectal point (IRP), on the rectal marker at 1cm in either direction from the defined rectal point were also recorded [Table 3] and expressed as ratio of rectal point dose in both positions, S Position and LM Position. It was observed that the doses at superior rectal point are relatively less as compared to doses at inferior rectal point for many patients in LM Position. We also recoded dose at superior and inferior points of Foley bulb with respect to bladder point dose. In S Position, the average ratio with bladder point dose for superior point is 0.59 and for inferior point is 0.54. Where as in LM positions the ratios are 0.58 and 0.62 respectively.

The dose [Figure 7] to ICRU Bladder point in LM Position shows considerable reduction. This is due to the compression of pelvic tissues leading to the movement of Henschke applicator creating a different geometry compared to S Position. Dose results [Figures 8 and 9] for pelvic wall showed that the applicator moved away posteriorly yielding a lower dose contribution from the ovoid and tandem sources. Dose to Rectal point [Figure 10] was analyzed and observed that the LM Position registered lower dose as compared to S Position. Also the applicator assembly seems to move inferiorly in LM Position. This leads to a substantial reduction in dose contribution from ovoid sources to Rectal Point.

When we searched literature we could find only two studies similar to the present study. Joelsson *et al.*,[18] used a Siemens gammameter employing small calcium sulphide solid state dosimeter to record dose rates with a probable error of ±10%. Differences in dose rates were reported between measurements in lithotomy and supine positions as percentages of values obtained with the patient in lithotomy position. The range of differences was large and the limits registered were −14% and +65%. The mean difference in dose rates at the posterior wall of the urinary bladder between the measurements in lithotomy and supine positions amounted to +12% indicating that bladder received higher dose in supine position. And the present

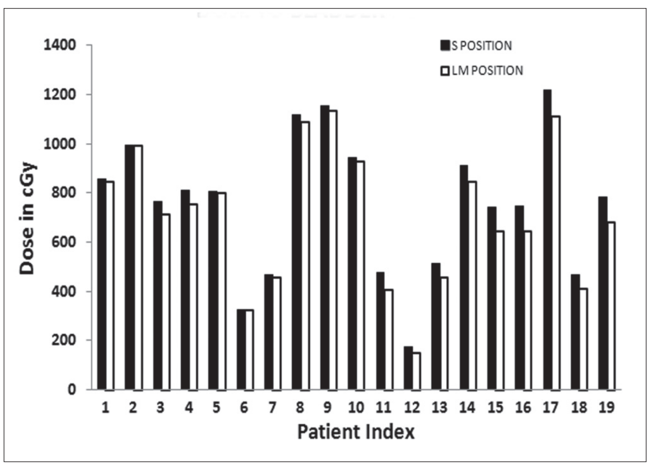

Figure 7: Dose to bladder point in two positions

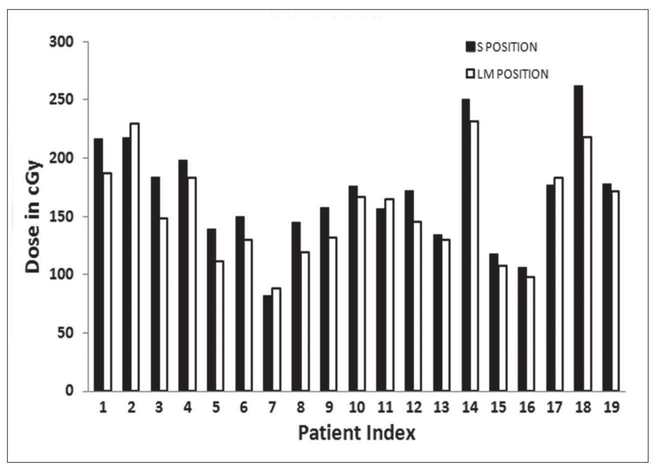

Figure 8: Dose to right pelvic wall point in two positions

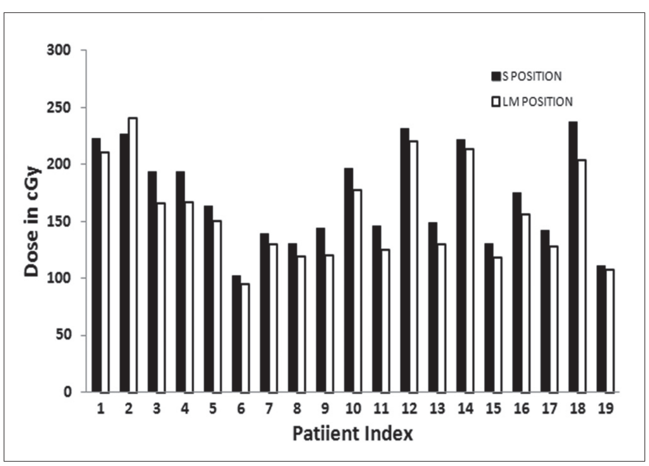

Figure 9: Dose to left pelvic wall point in two positions

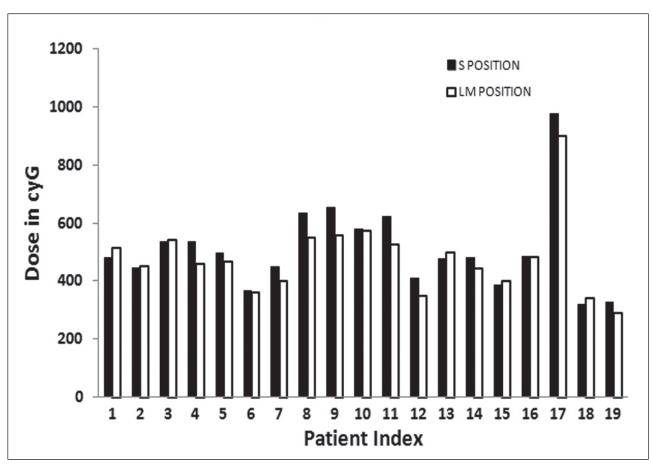

Figure 10: Dose to rectal point in two positions

Table 3: Doses to superior and inferior rectal points, at 1 cm in either direction from the defined rectal point, expressed as the ratio of defined rectal point dose

Supine position			*Lithotomy position*	
Superior rectal point	Inferior rectal point	Patient index	Superior rectal point	Inferior rectal point
0.97	1.04	1	0.81	0.97
0.94	0.95	2	0.92	1.00
0.90	1.04	3	0.88	1.15
1.19	0.92	4	0.38	1.13
0.86	1.05	5	0.84	1.13
1.03	0.83	6	1.22	0.92
0.72	1.06	7	0.34	1.03
0.68	1.18	8	0.48	1.46
0.69	1.23	9	0.48	1.37
0.92	1.04	10	0.91	1.08
0.91	0.94	11	0.87	1.06
1.32	1.53	12	1.02	1.82

study estimates an average 7% higher dose to bladder in supine position. The mean difference in dose rates at the anterior wall of the rectum, between measurements in lithotomy and supine positions, was −3%. This is in close agreement with our study, estimating a mean difference in dose as −5%. A corresponding difference between the mean values of the dose rates at the anterior wall of the rectum in supine and lithotomy positions was not observed to a degree as observed with bladder. The range of differences was about the same as in the bladder measurements, with a lowest value of −47% and a highest value of +34%. In the study by Joelsson *et al.*,[18] Radium sources were preloaded and the geometry of applicator, though different from the present study, gives an estimate of variation of doses due to change in patients position. In yet another study Yun HG and Shin KC[23] estimated the distance of bladder and rectal points from cervical os in supine and lithotomy positions. They concluded that the average dose to rectum is lower in lithotomy position and the average dose to bladder is lower in supine position. They used ICRU 38 dose reference points with modification in their study.

In our study we have chosen a modified rectal point linking it to the relatively rigid bony landmarks i.e., at the intersection of rectal marker and the line joining the centers of the right and left femoral heads on AP radiogram and on the rectal marker wire at the same level in the LT LAT radiogram. This makes it easy to identify the rectal point at the same level in both anatomical positions. A one to one dose analysis of each patient in both anatomical positions shows that about one third of nineteen patients exhibited relatively higher doses to rectum and lower doses to bladder in LM position. The dose differences range from 0.14% to 7% for rectum and −0.15% - −14.2% (for Patient no 16 in [Table 1]) for bladder. This shows that the increase in dose to rectum is compensated by the reduction of dose to bladder. All the above mentioned studies did conclude that the average dose to the selected population in case of rectum is lower in lithotomy position. Nevertheless it would be interesting to study large population. As brachytherapy procedure takes longer time, immobilization devices are required in Lithotomy Position to reproduce the patient geometry as well as to provide convenience for the patient from imaging to treatment delivery.

Conclusion

This paper presents the current study of positional dependence of dose to ICRU bladder, pelvic wall reference points and defined rectal point. It showed that the plans created in Lithotomy Position registered lower doses.

The decision of choosing the anatomical position i.e., either Supine Position or Lithotomy M position, for treatment planning and delivery can be taken based on proper analysis of comfort to patient and more importantly the doses to organs at risk. With regard to rectum the analysis of doses showed that in most of the cases, Lithotomy Position can give results equally good or better than in Supine position. Dose variation in bladder and rectum can be estimated in both the positions and the position that gives optimum doses can be chosen for the subsequent fractions. Even so interesting would it be to analyze and explore in detail the doses to organs at risk in 3D based planning.

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