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A Study On Analyzing The FF And FFF Photon Beam Dose Distribution In Vac-Lok Immobilization Device In Our Radiotherapy

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ABSTRACT

Immobilization devices plays a pivotal role in radiotherapy for treating various carcinomas. Due to the patient comfort and convenience, vaclok is one of the most frequently using immobilization device in radiotherapy for the treatment of cancer now a day especially for the thoracic region. The aim of the present study was to analyzes the photon dose distribution of flattening filter and free flattening filters beam in blue bag vac-lok immobilization devices in our radiotherapy department. The study was done with the help of parallel plate chamber and sp34 phantom for the surface dose calculation, and pdd and beam angle attenuation done by using Farmer chamber. The d_{max} of all photon energy were shifted up due to the presence of vaclok devices such as 1.6 cm to 0.8 cm,2.2 cm to 1.5 cm, for 6,10, MV, and 1.8cm to 1.0 cm,2.6cm to 1.8 cm for 6 &10 MV FFF beam. It was also observed that, the surface dose increased relatively due to the presence of vaclok irrespective of the all energy used, due to the presence of 10cm vacuum bag for the energies 6MV, 10MV, 6MVFFF and 10MVFFF were 46.98%, 54.25%,43.34% and 48.10% respectively. Similarly, for 20cm the relative dose increase was up to 49.21%, 57.46%, 45.90% and 51.17% for the energies 6 &, 10MV, and 6 & 10MVFFF respectively. The gantry angle attenuation for the 10cm vacuum cushion, maximum difference was found at the angle of 40°for 6MV, 10MV, 6MVFFF and 10MVFFF energies and corresponding difference noted was 3.91%, 3.19%,3.86%, 3.11%. The calculation was also done for the indexing lath attenuation on the vaclok, For the vacuum cushion of 10cm thickness with indexing lath, attenuation was found maximum at the angle of 40° with the values 7.01%, 6.00%, 7.05% and 5.60% for the energies 6 &10MVand 6 & 10MVFFF respectively. The results clearly show that the doses were attenuated with the introduction of vaclok and it varies with thickness as well as energy.

Keywords: flattening filter, free flattening filter, vaclok immobilization device, dose distribution, attenuation.

Introduction: Cancer is termed as a disease in which abnormal cells divide uncontrollably and invade the nearby tissues. They spread through the blood and lymph systems to other parts of the body. They are mainly cured by three major modalities medical, surgery and radiation therapy. Treatment may be carried as a lone way or as a combination of the treatments.

Radiation therapy uses ionizing radiation in the treatment of patients. Photon beam which are used for treatment may be a FF or FFF beam, each have its own pros and cons. The both type of photon have their own depth-dose characterisation. Flattening filter is a device used in linear accelerator for flatten the radiation beam, and make the beam homogeneous on the surface. They are mainly made up off with tungsten alloy material. In FFF photon beam, which is called free flattening filter this filter is not there, as a result they have a sharp dose at center with tapering dose at the periphery of the field. Radiation therapy aims at delivering an accurately measured dose of irradiation to a defined tumor volume with as minimal damage as possible to surrounding healthy tissue, resulting in eradication of tumor, high quality of life, and prolongation of survival or palliation of symptoms at a reasonable cost. Radiation therapy is favored as it improves the control of local tumors, enhances a specific symptom, provides better quality of life, or increases the possibilities of cure. The result of the radiation therapy treatment depends on the accuracy with which the radiation is been delivered. The uncertainty in the geometric reproducibility of the patient during the entire course of treatment may increase the

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volume of the normal tissue irradiated and might decrease the probability of controlling the tumor. To maintain a proper fixed and precise position in a ca radiotherapy, immobilization devices are the inevitable ones [1,2]. Immobilization and stabilization help in reducing the position uncertainty and helps to reproduce the patient setup during each fraction.

The immobilization devices should be cost-effective, provides patient comfort, lightweight for ease in setup and transport, durable and strong so that the immobilization device does not break during treatment. The device should attain properties such as to minimally affect the megavoltage beam and do not contribute to imaging artifacts which can affect the three-dimensional visualization of the anatomy of the patient for the identification of target or during imaging for the patient's alignment. The major objective of the immobilization device is to reproduce the patient's anatomical geometry at the simulation time and for all subsequent treatment fractions. The most common immobilization devices used are the thermoplastic mask, alpha cradle, vacuum cushion, breast boards, belly board etc.

A vacuum cushion is an immobilization device used for the accurate delivery of a prescribed radiation dose to the target volume while sparing the surrounding normal and critical structures.in our department this immobilization device was introduced recently. Vacuum cushion is made up of a plastic mattresses filled with radiolucent polystyrene (Styrofoam) beads. Complete vacuum is drawn through a quick-release valve, the cushion becomes rigid and comfortable mold, offering accurate reproducibility simulation and treatment. Vacuum cushions form a custom mould of a patient's anatomical contours allowing for proper positioning and reproducibility between treatments. The air is then vacuumed out of the cushion and sealed to retain the shape. Vacuum cushions are radio translucent. They can be recycled and are cost-effective. They are quick to set up and contains full range sizes. Vacuum cushions require a vacuum or wall suction. They require storage space and can puncture or develop leaks. The tangential lung exposure is more in the armrest when compared with the vacuum cushion[3]. Patients referred to be claustrophobic with the thermoplastic mask. Patients who are lean and bulky are much comfortably placed in a vacuum cushion than breast board[4].The use of a vacuum-fix device improved the transfer of the planned set-up from a simulator to the treatment unit than the breast board. The Breast-Vacuum cushion system was appreciably more effective than the Breast-PB system and therefore would provide a more accurate set-up [5,6]. They are useful for treating children, on cooperative patients, old and unstable patients also [1,7,8]. A study done by “Li Chen, Ying-Lin Peng,etc computed the dosimetric effects on the distribution of dose for immobilization devices used in head and neck cancers. They noticed considerable reduction in the coverage of the dose rate to the PTV and also the decreased mean dose of the target volumes. Their result showed that the skin dose on average was up to 53%. Hence they concluded that in order to account for the attenuation of dose and for the increment of skin doses the immobilization devices should be contoured and included for the calculation in TPS[9]. Another study done by Jong In Park, Sung-Joon Ye,etc investigated dosimetrically on how the immobilization devices effect the dose distribution using VMAT technique for lung cancer patients. They found that the target volume was considerably under dosed when the radiation beam was passing through the immobilization device. They also found that on the mean dose to the target volume was up to 5% and on average it was 2%. They concluded by stating that for the efficiency of the treatment one should contour the immobilization device and should account in for the dose calculation[10].This all study reveals the importance of the study of attenuation of immobilisation devices used in the radiotherapy.

This study aims to take into account the variation in the dose distribution of FF and FFF photon beams on a vacuum cushion in our radiotherapy center. The objectives taken into consideration

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in this study are to evaluate the changes in the dose distribution due to the vacuum cushion in terms of surface dose, various gantry angle attenuation, impact of indexing lath present in the vaclok device, and to analyze the Percentage depth dose and profile of the FF and FFF photon with and without vaclok.

Methodology: An observational study design is adopted and the study is conducted on behalf of and under the premises of the Department of Radiotherapy and Oncology, Kasturba Medical College Manipal.This study was performed with Elekta Versa HD linac for 6MV, 10MV, 6& 10MV FFF photon beams. The PTW 0.6cc farmer ionization chamber, Parallel plate ionization chamber PP40, PTW UNIDOS E electrometer, solid phantom SP34 (made up of polystyrene), Full body Vacuum cushions were used for dosimetry of various parameters. The effect of the vacuum cushion on the percentage depth dose was firstly measured using multiple Slab phantoms (SP34) and with the help of a parallel plate ionization chamber (PP40). The parallel plate ionization chamber was inserted into a special SP34 slab phantom designed to fit the parallel plate ionization chamber as shown in Fig 1& Fig 2. The energies used for irradiation were 6MV, 10MV, 6MVFFF and 10MVFFF. The irradiation was carried out without, with 10cm and with 20cm vacuum cushion which had uniform thickness. The data of measurement for depths from 0mm to 10cm were carried out using SP34 slabs of different thicknesses. In each depth, the source to surface distance (SSD) was set to 100cm, the field size set was 10×10 cm2 and MU's delivered were 100. 10cm of SP34 slab phantoms were used for backscattering below the specially designed SP34 slab phantom containing the parallel plate ionization chamber. Evaluation of the effect of various gantry angles on the absorbed dose due to the presence of 10cm and 20cm vacuum cushion was measured using a 0.6cc farmer ionization chamber. The irradiation was carried out for various gantry angles of 0◦ to 70◦ with 10◦ gantry interval. The energies used for the irradiation were 6 & 10 MV and 6 & 10 MV FFF. The source to axis distance (SAD) was set to 100cm and the field size set at 0 degree was 10×10 cm^2 and the MU's delivered were 100. For the backscatter, 9cm of SP34 slab phantom were used and 4.3cm as buildup above the specially designed SP34 slab phantom containing 0.6cc farmer ionization chamber.

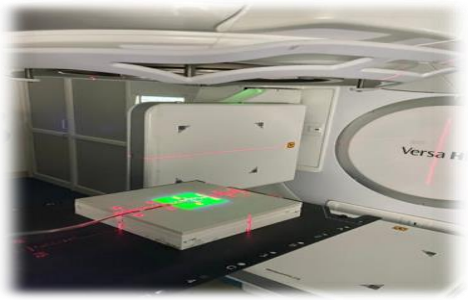

Fig 1: Setup used for the measurement of surface dose and pdd

Fig 2: Positioning of the vacuum cushion over SP34 slab phantom

The irradiation was carried out without, with 10cm and with 20cm vacuum cushion. In the next step, evaluation of the effect of the indexing lath of the vacuum cushion on the absorbed dose was measured without and with a 10cm vacuum cushion using a 0.6cc farmer ionization chamber. The irradiation was carried out for various gantry angles of 0 to 70° with 10° interval. The energies used for the irradiation were same as the previous one. The source to axis distance (SAD) was set to 100cm and the field size set at 0˚ was 10×10 cm2 and the MU's delivered were 100. For the backscatter, 9cm of SP34 slab phantom were used and 4.3cm as buildup above the specially designed SP34 slab phantom containing 0.6cc farmer ionization chamber.

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Results: The reading for the attenuation by the both FF and FFF photon beams on rectangular lath present in the vaclok were noted in table 1.

Gantry	**6 MV**		**10 MV**		**6 MV FFF**		**10 MV FFF**	
Angle	Without	With Lath In VL	Without	With Lath In VL	Without	With Lath In VL	Without	With Lath In VL
0	1	0.9434	1	0.954	1	0.94	1	0.9487
10	0.9981	0.9421	1.0052	0.9628	0.9926	0.9338	0.9881	0.9398
20	0.9931	0.9335	1.007	0.9587	0.9734	0.9128	0.9612	0.9105
30	0.9826	0.9161	0.9952	0.9434	0.9431	0.8763	0.9183	0.8658
40	0.9602	0.89	0.9823	0.9222	0.8992	0.8288	0.8658	0.8098
50	0.9186	0.8497	0.9476	0.8875	0.8368	0.7713	0.7985	0.7455
60	0.8298	0.762	0.8568	0.7991	0.7354	0.6705	0.6996	0.6495
70	0.6279	0.5605	0.6413	0.576	0.5115	0.4626	0.5041	0.4569

Table 1: Rectangular lath attenuation by FF and FFF photon beam

The PDD data collected with and without vaclok (10 and 20 cm thickness) for the energy 6 &10 mv with FF and FFF was shown in Fig 1, Fig 2 and table 2 below. The relative data for the effect of various gantry angles on the distribution of the dose without and in the presence of 10cm and 20cm vacuum cushion on energies for 6MV, 10MV, 6MVFFF, 10MVFFF is also tabulated below in table 3, respectively. The data is collected by using the SP34 slab phantoms, 0.6cc farmer chamber. 9cm of SP34 slab phantoms were used for the backscatter effect upon which a specially designed slab phantom which has a 0.7cm thickness to fit the 0.6cc farmer chamber was kept upon which 4.3cm of the slab phantom was kept. The source to surface distance was taken to be 100cm for all the angles with the field size of 10*10cm^2. The angles were taken from 0 to 70 degrees which involved the radiation field completely. This was done for all the 3 cases which involved without, with 10cm and with 20cm vacuum cushion

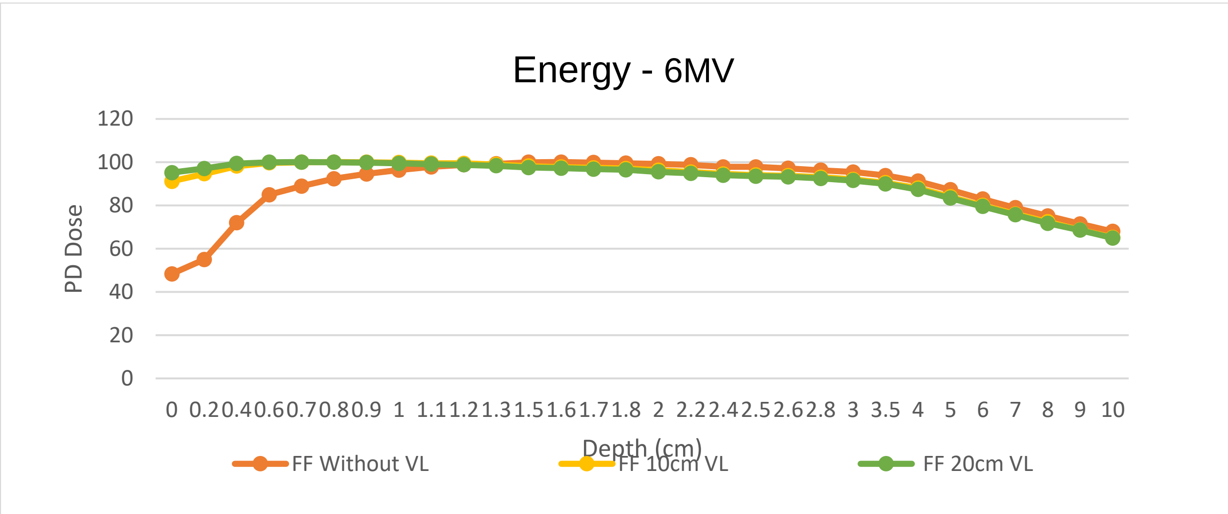

Fig 1: The effect of vacuum cushion on the PDD using 6MV FF energy

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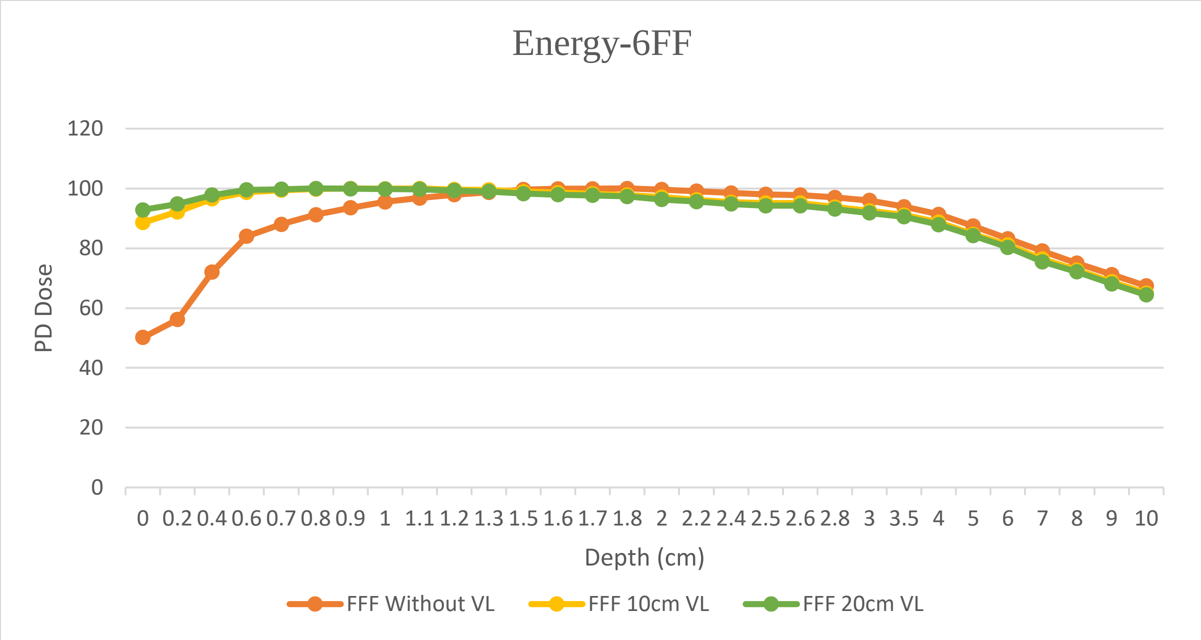

Fig 2: The effect of vacuum cushion on the PDD using 6MV FFF energy

Table 2: The effect of vacuum cushion on the PDD using 10 MV FF& FFF photon

Gantry	6 MV			6 MV FFF			10 MV			10 MV FFF		
Angle	Without VL	Vaclok 10 cm	Vaclok 20 cm	Without VL	Vaclok 10 cm	Vaclok 20 cm	Without VL	Vaclok 10 cm	Vaclok 20 cm	Without VL	Vaclok 10 cm	Vaclok 20 cm
0	100	96.64	93.93	100	96.60	93.74	100	97.41	95.18	100	97.17	94.90
10	99.87	96.46	93.68	99.47	95.99	93.15	101.08	98.25	95.84	99.04	96.28	93.88
20	99.30	95.89	92.99	97.60	94.11	91.19	100.84	98.01	95.82	96.28	93.40	91.06
30	98.16	94.50	91.85	94.46	90.82	88.17	99.94	96.92	94.82	92.07	89.02	86.92
40	96.08	92.16	91.27	90.19	86.33	85.34	98.49	95.30	94.39	86.74	83.63	83.15
50	92.03	88.63	88.37	84.03	81.23	80.73	95.24	92.41	92.17	80.02	77.57	77.51
60	83.38	81.36	80.85	74.32	72.42	71.92	86.69	84.82	84.52	69.71	68.27	68.16

Table 3: The effect of dose distribution for various gantry angles with and without vaclok

Discussion: Though the study on the influence of photon beams due to vacuum cushion was done, there was no data regarding the FFF photon beams. There was a lack of study on the

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Depth	**10 mv**			**10 mv FFF**		
cm	without	Vaclok 10 cm	Vaclok 20 cm	without	Vaclok 10 cm	Vaclok 20 cm
0	37.6	82.2	88.4	41.1	79.2	85.1
0.2	43.3	86.2	90.7	46.2	83.2	87.4
0.4	59.2	92	94.8	60.7	89.4	91.9
0.6	73.4	95.6	97.5	73.2	93.5	95.5
0.7	78.3	96.9	98.3	78.1	95.1	96.6
0.8	82.6	97.8	99	81.8	96.2	97.7
0.9	86	98.7	99.5	85.1	97.3	98.3
1	88.8	99	99.8	87.7	98.3	99
1.1	91.3	99.6	99.9	90.1	98.8	99.5
1.2	93	99.8	100	92	99.3	99.6
1.3	94.7	99.9	**100**	93.4	9.7	**100**
1.5	97.1	**100**	99.7	95.9	99.8	99.9
1.6	97.9	99.8	99.5	97.2	99.9	99.8
1.7	98.6	99.9	99.3	97.8	99.9	99.8
1.8	99.1	99.7	99	98.5	**100**	99.9
2	99.8	99.1	98.4	99.5	99.9	99.4
2.2	99.9	98.6	97.7	99.9	99.4	98.7
2.4	**100**	97.9	96.8	100	98.9	98.1
2.5	99.9	97.5	96.7	100	98.6	97.7
2.6	99.6	97.1	96.3	**100**	98.1	97.5
2.8	99.5	97.7	96.6	99.5	97.7	96.6
3	99.3	96.9	95.8	99.3	96.9	95.8
3.5	98	95.2	94.4	98	95.2	94.4
4	95.9	92.9	91.8	95.9	92.9	91.8
5	91.8	88.9	87.6	91.8	88.9	87.6
6	87.6	84.8	83.8	87.6	84.8	83.8
7	83.7	81.1	80	83.7	81.1	80
8	79.8	77.4	76.3	79.8	77.4	76.3
9	76.1	73.5	72.7	76.1	73.5	72.7
10	72.4	70.1	69.3	72.4	70.1	69.3

influence of photon beams in the vacuum cushion of a particular thickness. There was no study regarding the attenuation due to the indexing lath of the vacuum cushion. A study conducted by Keyvan Jabbari, etc. assessed various characteristics of dosimetry for the immobilization because of the presence of vacuum-bag. They concluded that the effect of vacuum bag in their normal use and in large depths, reduced the depth dose to <1% for 6Mv and 18Mv energies and it was neglected in the correction for physics calculation. They used a vacuum bag for various thicknesses ranging from 8 to14 cm and found out that the attenuation was up to 2.5% and 1.2% for 6 MV and 18 MV photon energies of the primary beam. They noticed the increase in the surface dose up to 30% and 25% for 6MV and 18MV [11]. The data for the FFF beams on the different thicknesses of the vacuum cushion for different gantry angles had not been developed. Radiotherapy treatment involves risk because even a small error in the patient positioning, dosimetry or treatment delivery can lead to a negative consequence. Thus accurate delivery of the radiation dose to the tumor site is very important. This varying dose in the first few depths contribute to the increase in the surface dose which alters the prescribed dose delivered to the tumor site. It was observed that the surface dose increased relatively due to the presence of 10cm vacuum bag for the energies 6MV, 10MV, 6MVFFF and 10MVFFF were 46.98%, 54.25%, 43.34% and 48.10% respectively. Similarly, for 20cm the relative increase was up to 49.21%, 57.46%,45.90% and 51.17% for the energies 6MV, 10MV, 6MVFFF and

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10MVFFF respectively. This increase in the surface dose is caused due to the increase in the contribution of primary and secondary scattered electrons. This increase in the surface dose reduced significantly when the energies crossed a certain depth. It was noticed that for the energies 6MV, 10MV, 6MVFFF and 10MVFFF the increase in the surface dose stopped varying significantly above 1.3cm, 1.8cm, 1.3cm and 2cm respectively. This decrease in the skin sparing effect is the reason for the radiation burns observed in the patient when treated using posterior anterior fields. As noticed for 10cm and 20cm vacuum cushions the attenuation caused at various depths indicate that the attenuation must be taken into consideration as it causes the difference in the MU calculations. During the breast treatment delivery and while using treatment delivery techniques such as DMLC and VMAT the effect caused due to the presence of various gantry angles should be considered. A paper done by "Stephen McCormack, Jennifer Diffey, etc." found that as the gantry angle was increased the beam attenuation also increased significantly. The attenuation for the 6MV energy was found to be 2.2% at the 0 degrees and 8.7 at 70 degrees. They took the relative readings for the carbon couch with 5cm and 10cm either side laterally in order to take into account the shift that might be produced during the patient immobilization. They suggested two ways to compensate the attenuation. Firstly, they considered a correction factor which was 5% for the posterior oblique beams and the second compensation suggested was to contour the carbon fiber couch during the treatment planning so that it would accordingly calculate for the beam attenuation[12]. The values from the table 3, illustrates that as the gantry angle is increased there is a decrease in the depth dose when the vacuum cushion was placed in the field of radiation. For the 10cm vacuum cushion the maximum difference was found at the angle of 40° for 6MV, 10MV, 6MVFFF and 10MVFFF energies and corresponding difference noted was 3.91%, 3.19%,3.86%, 3.11%. For 20cm vacuum cushion the maximum difference for 6MV, 6MVFFF and 10MVFFF energies was found to be at 20° with corresponding difference of 6.31%, 6.41% and 5.22%. For 10MV energy the maximum difference obtained was at 10° with the difference of 5.24%. This may be due to the increase in radiation path through the cushion which finally results in secondary electron production.

There was situation during thorax treatment that the indexing lath of vacuum cushion may have been present in the treatment path. The notably difference for the dose attenuation at various gantry angles are illustrated in table1. For the vacuum cushion of 10cm with indexing lath placed in the radiation field attenuated maximum at the angle of 40°with the values 7.01%, 6.00%,7.05% and 5.60% for the energies 6MV, 10MV, 6MVFFF and 10MVFFF respectively. So, we should take into account the attenuation effects of the indexing lath, while planning, so as to place the beam in such a way that the indexing lath should not hinder the radiation path.

Conclusion: All the results from the above collected data indicate that there is a considerable dose attenuation due to the presence of the vacuum cushion with all energy. The surface dose is shown an increase in dose with FFF beam than FF beam, gantry angulation effects is same in all energy with large attenuation in larger angle. As the thickness of the vaclok increase the surface dose is also increasing. The attenuation due to the presence of the vacuum cushion during the radiotherapy department is unavoidable. This attenuation can adverse the prescribed dose delivered to the target. The target might be under-dosed failing the delivery of the prescribed dose which may lead to the reoccurrence of cancer. Therefore, in order to deliver the prescribed dose to the tumour volume the attenuation due to the presence of the vacuum cushion must be taken into account during the contouring as well as the treatment planning.

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