

Analyzing The Photon Energies Depth Dose Distribution and Dose Profile of Blue Bag Cushion Immobilization Device Using Radiation Field Analyzer

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Abstract

Breast carcinoma is one of the major causes for death in woman worldwide. Adjuvant radiotherapy seems to be one of the best treatment modalities for such type of carcinomas. The success of this type of radiotherapy depends on its accuracy and reproducibility, which can be possible with the help of different immobilization devices. So, it is very important to evaluate the radiation attenuation properties of each immobilization devices. The study here mainly focuses on the attenuation properties of the blue bag (one of the immobilization device used frequently in our department for thoracic region) by 6,10,15 MV flattening filter and free flattening filter. Parallel plate chamber, semi flex chamber with solid phantom and radiation field analyzer were used for the study. Study was done for beam surface dose, depth dose and profile measurement. There was a vast change in the surface dose with introduction of blue bag, with a ratio of 47%,54%,56%&43%,48% in 6,10,15 MV &6,10 MV FFF in 10 cm thickness and 49%,58%,60% & 45.6%,52% in 20 cm thickness blue bag respectively. There was a change in the depth dose maximum with a shift towards the surface with an average of $50\pm 10\%$ with the introduction of blue bag in all photon energies. The percentage depth dose difference between with and without blue-bag cushion is negligible after certain depth, when compared with the surface dose in all energies. The profile of all photon energies also shows the influence of blue bag in the radiation field with an isodose curve tilt in the thicker part. From the above results it was clear that both the profile as well as attenuation by the blue bag was significant and it should be considered during the planning part.

Keywords: Radiation field analyzer, Blue bag cushion, Flattening filter, Free flattening filter, Dose attenuation

Introduction

Breast Cancer is termed as a disease in breast, where cells divide and grow uncontrollably. CA breast is considered as one of the most common and leading cancer, causing death in woman worldwide ^(1,2,3). Adjuvant radiotherapy with chemo and surgery is a promising treatment modality in these types of carcinomas. There are so many advanced treatment techniques and new systematic therapeutic options to deal with these. The main aim of radiotherapy is to target maximum cancerous cell with sparing the normal tissue, this is possible only with a proper positioning and reproducibility of the patient on daily treatment basis ^(4,5). With the introduction of so many new immobilization devices in market, each department has got the freedom to use their own immobilization system for specific cancers with new treatment technique and protocol.

Due to the pendulous nature, size and breathing movement treating carcinoma in breast using radiation is difficult without proper immobilization devices. For that reason, there are more than one

immobilization devices developed for carcinoma breast cases. The most commonly used immobilization devices such as breast board, thermoplastic mould, blue bag cushion etc., besides this alpha cradle, wireless bra, breast ring, breast cup, stocking, adhesive tape-shaped breast plates are used. The most important property in all types of immobilization devices used in the radiotherapy is that it should be radiolucent and should be provide maximum comfort to the patient. Since all these devices are made up off with different materials their attenuation will also be different. The blue bag cushion is an immobilization device, filled with polystyrene foams inside a blue styropore nylon fabric which is radiolucent. The blue bag cushions are custom formed for positioning accuracy and become rigid when vacuum is applied. There is a valve connected to one end of the blue bag body cushion, through which the air can be pumped as well as sucked out with the help of a body fix vacuum pump to get the body impression of the patient as in fig 1. Once the desired impression is achieved there is a stopper to close the valve to prevent the air from entering the cushion. Vacuum Cushions create a comfortable, stable and precise mould of the patient's position for up to six weeks They can be used for different clinical set-ups such as SBRT, VMAT, IMRT etc., and indications such as CA lung, pancreases, stomach etc. There were several studies conducted on the comfort and ease of the vacloc cushion with other immobilization devices. A study done by Jassal K, Bisht S, Kataria T suggests that vacuum cushions were more comfortable for bulky patient than breast board ⁽⁶⁾.



Fig 1: blue bag vacuum cushion & body fix vacuum pump

The study done here was mainly focused on the dose distribution of blue bag cushion using radiation field analyzer by 6,10,15 MV flattening filter and 6,10 MV free flattening filter of the Elekta Versa HD LINAC in our department. Free flattening filter is a new modality of treatment where the flattening filter in the radiation beam will be removed, and the beams are allowed to pass to the patient with high dose at beam central axis and steep gradient dose at both the ends as shown in fig 2. By doing so the dose rate of the beam can be increased, with the treatment time being increased, with no scattered beam from the filter itself.

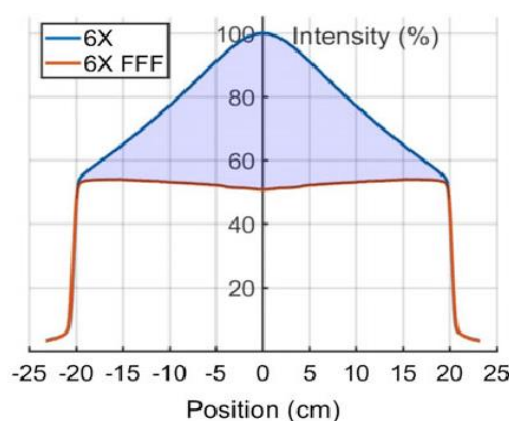


Fig 2: cross-profile of 6 FF &FFF photon beam

Method and material: This study was conducted using parallel plate chamber to measure the surface dose of each photon energy in water equivalent polystyrene phantom at source to surface distance 100 cm and 10x10cm² field size as in fig 3a. A back up of phantoms were used to take care of the backscattered photon, surface dose due to the blue bag cushion with different thickness was also calculated by adding the cushion on the top of the slab phantom for each energy with the same source to surface distance. Readings were measured using the electrometer (PTW UNIDOS E) connected to the chamber by cable. Another problem which we had to face was the overresponse of the chamber in the build-up region due to the scattered electrons from the chamber itself. To solve this, we used the Gerbi's overresponse correction factor for the chamber

$$F(d, E) = P(d, E) - (0, E) e^{-\alpha(d/d_{max})}$$

$$(0, E) = [-1.666 + (1.982 IR)] \times (C-15.8) (\%/mm)$$

(0, E) is the energy dependent chamber factor that indicates the overresponse per mm of chamber plate separation at the surface of the phantom. The values -1.666, 1.982, and 15.8 are constants that were taken from the graph, which represent the % maximum ionization per mm of plate separation at the phantom surface plotted as a function of guard width or collector edge-sidewall distance⁽⁷⁾.

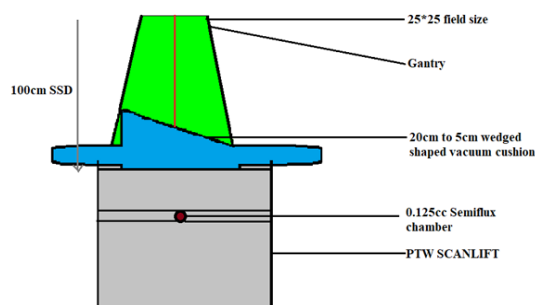
IR = ionization ratio at depths of 20 cm and 10 cm, which is measured at a fixed source-detector distance and 10 × 10 cm² field size, F(d,E) is the corrected percent depth dose, P(d,E) is the relative depth ionization energy, d_{max} is the maximum dose depth, C is the sidewall-collector distance (0.35 mm for PTW-Markus 23343), l is plate separation (2 mm for PTW-Markus 23343), 5.5, α constant, d depth of the chamber front window⁽⁸⁾.

The alignment of phantom is such that the, chamber surface was always facing the central axis of beam. All the measurements were performed at source to skin distance (SSD) 100 cm to the surface of the chamber. The percentage depth dose was calculated using the field as well as reference semi flex chamber in water phantom.

The study was also done for the profile of the photon beams, to rule out the effect of blue bag cushion. Two semi flex chambers were used, one as reference and other as field chamber, this will help to reduce the dose rate fluctuation in the output. The crossline profiles were taken using the radiation field analyzer phantom with water using semi flex chamber for 6,10,15, &6,10 MV FFF beam at a depth of 5 cm. A wedge-shaped blue bag cushion of height 20 to 5 cm was created for measuring the beam profile. The blue bag cushion was kept in such a way that the bag, just touches the surface of water phantom without disturbing the both the chamber as shown in fig 3b.



Fig 3a: Setup for surface dose measurement



3b: Profile measurement for blue bag cushion

All the measurements were conducted using Elekta Versa HD linear accelerator which can produce photon energies of 6,10,15 MV & 6,10 MV FFF beams in our department.

Results

The data for surface dose was measured using parallel plate chamber and SP34 phantoms for all photon energies (6,10,15, & 6,10 FFF) with 100 monitor unit is given below in fig 4.

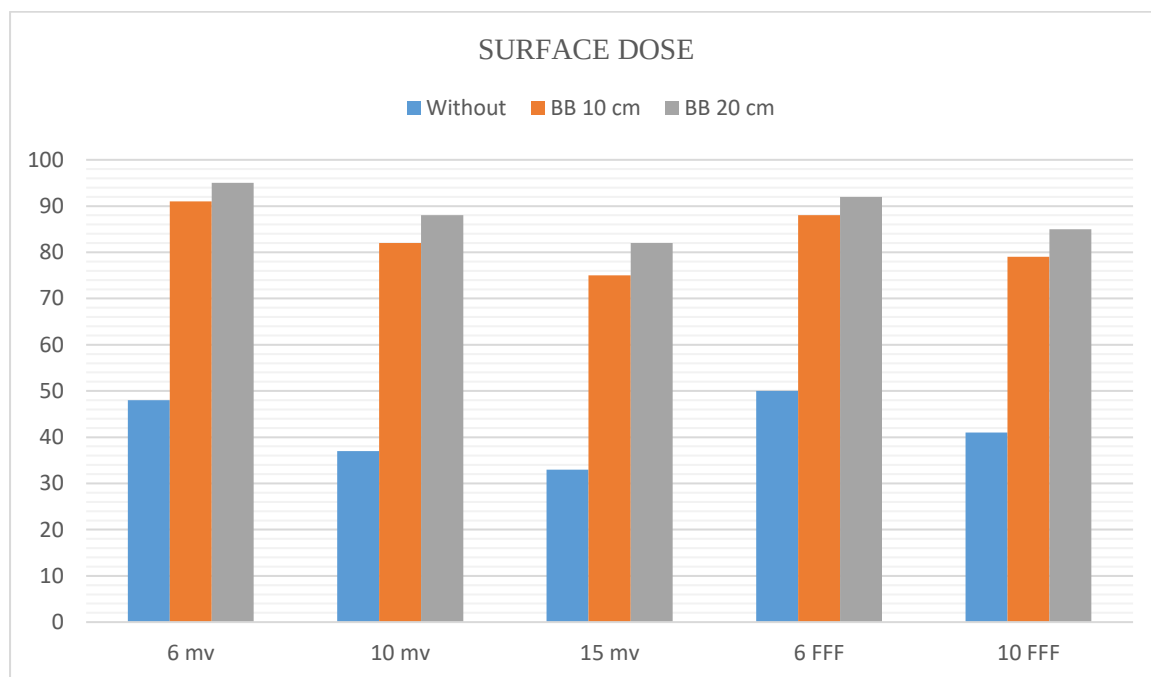


Fig 4: Surface dose measurement using parallel plate chamber

The percentage depth dose measurement using semi flex chamber and water phantom at 100 source surface distance and field size of 10x10 cm² was also taken and displayed in fig 5a. The measurement was taken for 10 cm and 20 cm blue bag cushion device also displayed in fig 5b & 5c. Horizontal axis shows the depth in mm and the vertical axis shows the relative dose.

While doing all the measurements special care was taken that the air valve inlet and the lath below the blue bag was not in the radiation path

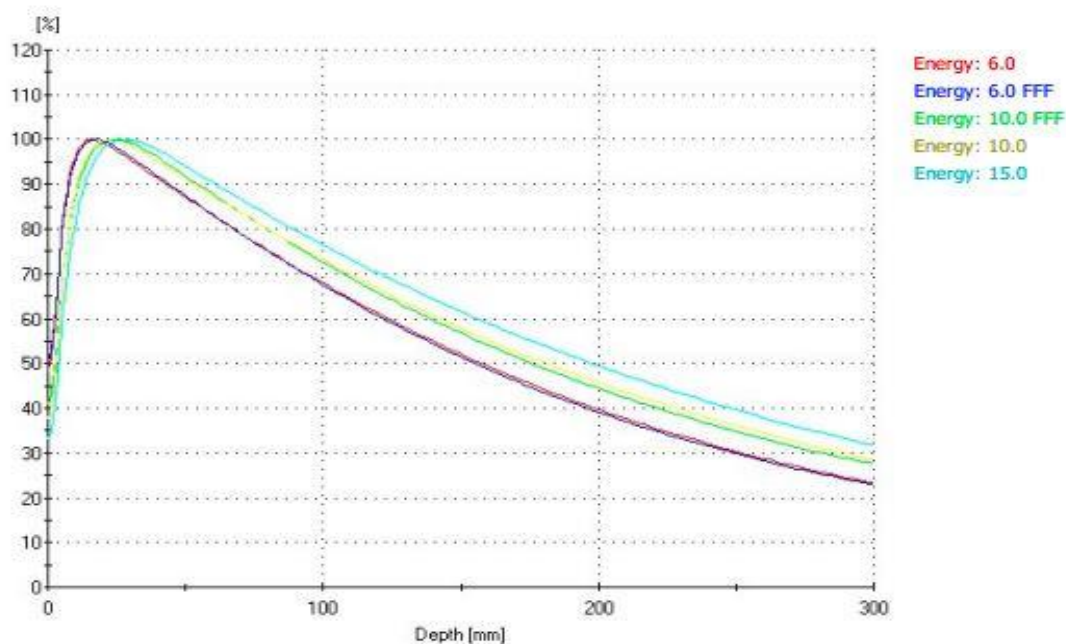


Fig 5a :Percentage depth dose of photon energies without blue bag cushion

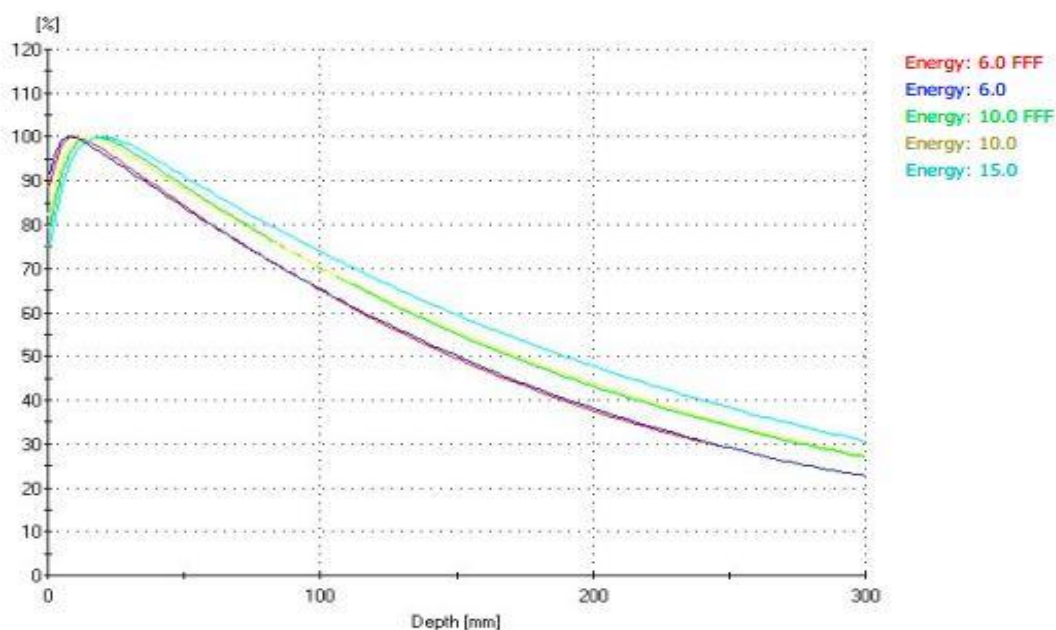


Fig 5b: Percentage depth dose of photon energies with 10 cm blue bag cushion

The combined crossbeam profile obtained with and without a wedge-shaped blue bag vacuum cushion with a minimum thickness of 5cm and a maximum thickness of 20cm is graphically illustrated below in figure 6a & 6b respectively. The profiles were taken at a field size of 25x25 cm². The readings obtained were graphically analyzed using a mephysto software of PTW dosimetry. The flatness as well as symmetry of the beam were changed due to the introduction of the blue bag cushion.

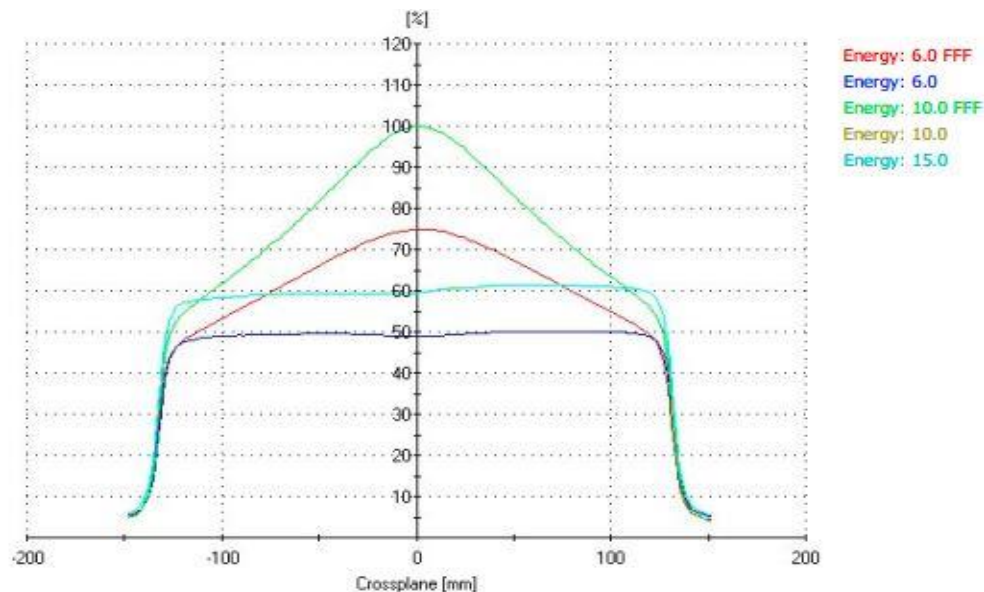


Fig 6a: Graphical representation of the beam profile of all photon energies without blue bag cushion

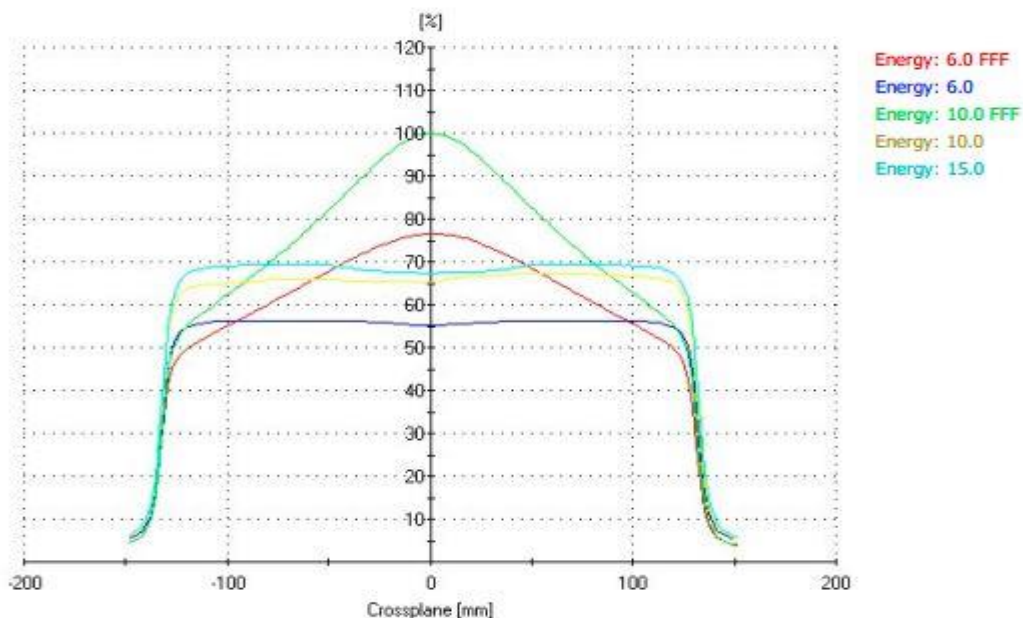


Fig 6b: Graphical representation of the beam profile of all photon energies with wedged blue bag cushion

Discussion

Main goal of the radiotherapy is to maximize the tumor damage with the normal tissue sparing, since it 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. From the result the percentage depth dose varies substantially with increase in surface dose for the energies 6MV, 10MV, 15MV, 6MVFFF and 10MVFFF, in the initial few depths when the vacuum cushion was placed in the field of radiation. This increase in the percentage dose reduced significantly when the energies crosses a certain depth. There was a vast change in the surface dose with the introduction of blue bag, with an increase in ratio 47%,54%,56% & 43%,48% in 6,10,15 MV & 6,10 MV FFF in 10 cm thickness and 49%,58%,60% & 45.6%,52% in 20 cm respectively. This

is due to the scattered secondary dose from the blue bag cushion. Therefore, special attention was taken when placing any posterior beam through the blue bag for thorax as well abdomen cases. In his study Keyvan Jabbari, etc. assessed various dosimetric characteristics in the presence of vacuum-bag on two energies. 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 noticed the increase in the surface dose up to 30% and 25% for 6MV and 18MV ⁽⁹⁾. Thus, in short, we can tell that introduction of bluebag cushion in the radiation field will result in the unusual skin burn, due to the bolus effect of the blue bag cushion.

Regarding the percentage depth dose using semi flex chamber, it was observed that after a particular depth especially after 2-3 cm, the difference between with and without blue bag cushion was not so significant as the surface dose, in all energies. For a depth of 10 cm, it was 67.9%,73.1%,76.4%,67.4%,72.4% for 6,10,15 MV & 6,10 MV FFF beam without the cushion and 65.2%,70.3%,73.8%,65.0%,70.1% & 64.9%,69.5%,73.0%,64.4%,69.3% for 10 cm and 20 cm blue bag cushion respectively. The percentage depth dose difference at 10 cm depth between the 10cm and 20 cm cushion bag is negligible.

It is unlikely to have 20 cm of the VB thickness on the real clinical scenario, however while treating a tangential beam there may be a chance that the beam may have to travel for more than 15 cm through the blue bag, depending upon the thickness on the lateral side and the beam angle chose. Fig 7 shows the beam profile differences between with and without blue bag for 15MV photon obtained with water phantom. Setting up the profile measurement using water phantom and blue bag cushion is tedious process. We had to make precisely a wedge-shaped blue bag with flat surface below which had to touch with the surface of water. We can only take profile at a depth greater than 4 cm. There were studies done with mapcheck with array detector with accurate measurement dose at 2 cm from the surface, since mapcheck has a buildup of 2 cm within itself surface dose measurement is not possible with that^(10,11).

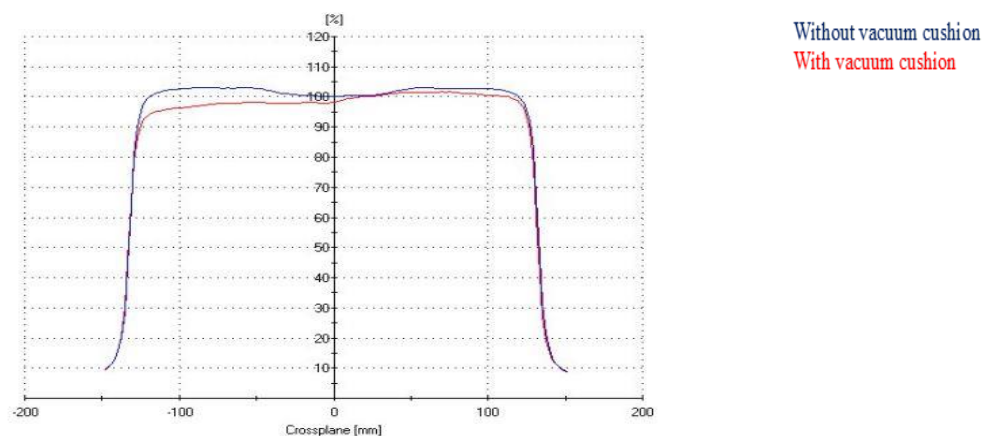


Fig7: Beam profile obtained with and without blue bag cushion for a 15MV energy

Conclusion

Introduction of the blue bag cushion in the radiation path will definitely cause attenuation in the beam, and this attenuation will be more pronounced when the thickness of the blue bag cushion increases. There was a considerable decrease in the depth dose maximum up to a certain depth with the introduction of blue bag with vast increase in skin dose. The study also shows that; profile of the beams also will get influenced by the introduction of the blue bag cushion. So special attention should be taken when any immobilization devices are present in the radiation path during treatment as well as simulation.

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