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Quantification and modelling of the dosimetric impact of the treatment couch in volumetric modulated arc therapy (VMAT)

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► ***Original article***

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ABSTRACT

Background: As the volumetric modulated arc therapy (VMAT) becoming a main role of treatment ways, the effect of couch top becomes more significant. It is imperative to re-evaluate the couches that previously may have been considered of no importance during early treatment techniques. The impact of couch top on radiation delivery was explored and the couch model was tested with the aim of reducing the couch absorption influences. ***Materials and Methods***: Attenuation measurements were performed in a cylindrical phantom with an ionization chamber positioned at the isocenter. Couch model was obtained by importing its actual CT scan, and the accuracy was evaluated by comparing percentage deviation at 2 and 5 mm voxel grid size. Effects on surface dose were measured using EBT3 film with the constant SSD at different depths and beam energies at the gantry angle 180° and 0°, respectively. ***Results:*** Couch top increases surface dose from 45.9 % to 95.8 % , from 35.0 % to 87.9 % and from 29.2% to 73.9 % for 10 cm ×10 cm field at 6 ,10 and 18 MV, respectively. Due to the couch absorption the case of vertebral metastasis VMAT plan D50 of the PTV changed from 30 Gy to 29.3 Gy. Couch model with uniform electron density of 0.18g/cm3 demonstrated an excellent agreement between measured and TPS computed dose. ***Conclusion:*** The treatment couch presence between the patient and beam source significantly alters dose in the patient. Modelling the couch in the Monaco TPS can adequately predict the altered dose distribution.

Keywords: *volumetric-modulated arc therapy, treatment planning system, attenuation, buildup, Couchtop.*

INTRODUCTION

Modern technologies [such as intensity-modulated arc therapy (IMAT), volumetric modulated arc therapy (VMAT) and image-guided radiotherapy IGRT)] in external-beam radiation therapy have drastically increased the therapeutic window and now are the most powerful methodologies for the treatment of localized tumours. The management of the patient with cancer has evolved into a complex, closely integrated application of sophisticated technology to evaluate and therapy the tumour and, using various modalities, to obtain optimal therapeutic results, emphasizing the quality of life of the patient. Uncertainty in the radiation treatment process could lead to major changes in patient outcome, the therapeutic ratio decreases as the uncertainty increases and vice versa, depending on the magnitude of the error.

The carbon fiber couches are commonly used

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in radiation therapy. It is assumed that radiation attenuation is minimal [1, 2] because carbon fiber couches have low density and it is notgenerally accounted for during treatment planning. With the introduction of intensity-modulated radiotherapy (IMRT) the number of fields used for patient treatment increases, the effect of treatment couches becomes more significant [3-5]. Consequently, it leads to a major dosimetric mistake [8]. Especially as the advanced VMAT delivery systems becoming a main role of treatment ways, which places even greater demands on delivering accuracy [6, 7]. It is imperative to re-evaluate the treatment couches that previously may have been considered of no importance during early treatment techniques.

Some researchers has been investigated a variety of couch designs reported that the carbon fiber table decreasesthe skin-sparing effect and causes dose attenuation [9-14]. Attalla *et al.* [15], investigated the effect of the Siemens Primus couch on depth dose measurements for normally incident photon beams. An increase in skin dose for a 6 and 10 MV photon beam increases from 24% to 62%, 16% to 44% respectively, was reported. A study with the Varian Exact couch (standard couch) performed by Heng Li *et al.* [5] showed that the highest dose difference between rails set at the "in" and "out" positions was 2.6% and 2.1% in the IMRT and VMAT case.

The impact of iBEAM evo Couchtop EP installed on Elekta Synergy® Linac for patient positioning during treatment delivery, which has interchangeable extensions, and features a low-density foam interior surrounded by a thin layer of carbon fiber [16]. The investigation has been explored by several research groups on several different commercials treatment planning systems with different calculated algorithms [10-12, 17-20] [12]. And they reported that the pencil beam and convolution algorithms failed to accurately calculate couch attenuation. Monaco treatment planning system is employ Monte-Carlo calculation algorithm, Shortt *et al.* [21] demonstrated its high accuracy against measurements in heterogeneous geometries and is currently routinely used as a gold standard against which to compare analytical methods. Extensive literature searches have revealed little published work on Couchtop EP using Monte-Carlo calculation algorithm. Our recently published paper examined this couch's extensions parts (Extension 415, which was used for treatment head and neck cancer) dosimetric properties for normal incidence photon beams [22], and proposed the systematic introduction of the uniform couch model in clinical routine. As yet, however, no investigation has been performed to show this effect for iBEAM evo Couch top EP.

This paper reports on the effect of the iBEAM evo Couchtop EP on beam attenuation, surface dose and dose in the buildup region for different beam energies and, uniquely, different gantry angles. One case planned with VMAT was selected and calculated on the actual patient anatomies with and without couch modeling to determine potential clinical effects. The accuracy of iBEAM evo Couchtop EP couch model modeled in the Monaco TPS for simulation the beam attenuation due to the presence of the Couchtop EP is also reported.

MATERIALS AND METHODS

Phantom dose measurement

This research took place at Medical Faculty Mannheim of University of Heidelberg, Manheim Clinical Center facilities and the Fourth Hospital of Hebei Medical University in department of radiation oncology. Data was collected using Elekta Synergy® Linac. The direct attenuation measurements were made using a 0.125cc Semiflex ion chamber isocentrically placed in the center of a homogeneous Cylindric sliced RW3 IMRT head/neck phantom model T40015 (PTW Freiburg, Germany). The phantom was positioned by means of acrylic circular bases on two sides of the cylinder, and 7cm high form the couchtop. Each of these measurements was made at all of the treatment modality for the same field size: 10×10 cm^2 and at SAD 100 cm irradiated 200 MU. The positioning of the ionization chamber at the system's isocenter

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results is a constant source to detector distance as the gantry is rotated around the phantom. First, this set up was used to make initial dose measurements at the machine's isocenter given an angle of incidence of 0°. Further measurements were taken at varying degree intervals between the 180° incident beam to beams reaching one side of the couch, in 10° increment, for the purpose of monitoring the change in attenuation for given beam paths through the treatment couch. Comparing these measurements with the dose collected without passing through the treatment couch produced the percentage by which the beam was attenuated by the treatment couch. Attenuation was defined as equation 1:

$$Attenuation = \frac{D_{nc} - D_{pc}}{D_{nc}} * 100\% \quad (1)$$

Where D_{pc} represents the dose measured with the beam passing through the treatment couch and D_{nc} represents the dose measured with the gantry angle set for 0° while the beam did not intersect the treatment couch.

Couch modelling in the Monaco TPS

In order to include the iBEAM® evo Couchtop EP in the planning system, the insert was CT scanned with the slice thick is 2 mm and the images were uploaded into the Monaco version 3.3 treatment planning system. From these CT images each structure of the couch was traced and saved in treatment couch model library. The couch structure set was then imported into a treatment plan including a model of the RW3 water-equivalent material in cylindric phantom, and dose calculations were made using the new plan including the copied couch structure set in figure 1. Each experimental setup was first measured on the linac and then replicated at the planned in the TPS in order to mimic clinical use. In our simulation we choose calculate dose to medium and request that all the simulated per plan Monte Carlo relative standard deviation ≤ 0.5%. Moreover, in the Monaco TPS, before dose calculation structures must be converted to 3D voxel grid [23], Monaco needs to determine what percentage of a voxel is included as part of the structure when only a portion of the voxel falls inside the structure [22]. Two different calculation grid resolution 2×2 × 2 mm^3 and 5 × 5 × 5 mm^3 were used to evaluted the "voxelized" influence. The couch modeling simulated results in the Monaco TPS were evaluated using the Percentage Deviation (PD) equation (2) between the measured and calculated dose, defined as the follows, and use the measurements dose as the reference dose.

$$PD = \frac{D_{calculated} - D_{measured}}{D_{measured}} * 100\% \quad (2)$$

Where $D_{cal.}$ is the calculated dose in the Monaco TPS and $D_{meas.}$ is the measured dose at the same point in the phantom. By changing the assign electron densities (ED) dialogs of couch model to find the best electron densities for the modeled couch top.

Dose buildup measurements

Dose buildup measurements were performed with EBT3 Gafchromic® film (International Specialty Products, NJ) on the Linac with a (10×10) cm2 square field on a solid water phantom surface. Gafchromic® films were placing between slabs at four different water equivalent depths at 1mm, 5mm, 10mm and dmax (15mm, 20mm and 25mm) in the water-equivalent RW3 slab phantoms and placing the solid water with the constant SSD 100cm such that the top edge of the phantom was even with the central axis of the treatment delivery system at the gantry angle 0° and 180° for without and with couch inserted. To decrease the couch top backscatter, at least 4cm slabs are placed below the radiation film. For each measurement the film was irradiated with 400 MU at different treatment modalities (6MV, 10MV and 18MV). Films were digitized with an Epson (Tokyo, Japan) Expression10000XL/PRO scanner. A Gafchromic® EBT-easel was used for exact repositioning of the films on the Expression scanner. In order to correct for the nonunifomity of the light field and the scanner area [24, 25], a scan of a non-irradiated film was made prior to film irradiation and was subtracted pixel-by-pixel from all irradiated films, including the calibration film [26]. And the scanned film were saved as *.tif type file and

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imported into the the ImageJ (National Institutes of Health) software. Use the ImageJ software to extract the red channel intensity value, and the intensity value is adjusted in such a way that 1 MU corresponds to a dose of 1 cGy delivered in a water phantom at the depth of dose maximum on the central beam axis when irradiated with a 10×10 cm2 field at a SSD of 100 cm. The mean density and standard deviation were analyzed by 5×5cm2 square area at the center of the film to get the dose value.

Clinical case study

To evaluate the magnitude of the loss of skin sparing using the modeled couch, we solely choose a "worst-case" scenario investigated the buildup effect of the iBEAM® evo couch top EP on the actual patient anatomies with and without couch modeling to determine potential clinical effects. The procedures were approved by the institutional review board of Hebei Medical University (Grant No.2018MEC089) and were performed in accordance with the ethical standards of human experimentation and with the Helsinki Declaration of 1975, as revised in 2000. A 70-year-old man with spinal cord compression syndromes caused by lung cancer vertebral body metastasis was selected for the study. The treatment planning target volume (PTV) was delineate from the ninth thoracic vertebra to the eleventh thoracic vertebra. Plans were optimized according to the VMAT technique with three partial arcs Arc1 (180° to 220°), Arc2 (320° to 40°) and Arc3 (140° to 180°) and all arcs with an increment of 20 (The increment setting on the geometry tab in the beam control dialog box controls the number of generated static gantry positions or sectors.). For PTV the prescription dose is 30 Gy in 10 fractions. Cord, heart and lung were defined as organs at risk (OARs). For the patient, two sets of plans were optimized for 6 MV photon beams with and without Elekta iBEAM® evo Couchtop model was included. All plans were developed with the Monaco TPS and dose calculations have been performed with the Monte Carlo algorithm, with a grid size of 3mm. Plans data evaluation were performed with DVH and transverse dose curves.

Data analysis

Microsoft Excel which forms part of the Microsoft Office 2010 was used to analyse the recorded measurements and the simulated dose. The software was used to calculate the measured and TPS simulated couch attenuation as well as percentage deviation and relative attenuation of the couch using equations 1 and 2 respectively. It was also used in finding the best model, we summed the deviations of the doses at different angles. We considered the model with the least sum of the deviation from zero as the best model. Since the sum of deviations from the mean is zero. We also used Student paired *t-test* to further analyze the data. The null hypothesis was that the percentage deviation of Monaco simulated dose and the measured dose are equal. The data at a specific angle were considered paired for data analysis. The null hypothesis would be rejected if the p-value is less than 0.05 (meaning the TPS dose and measured dose are significantly different at the 95% confidence level.) [17]. A mathematical analysis tool called MATLAB was used to plot graphs used in the data examination.

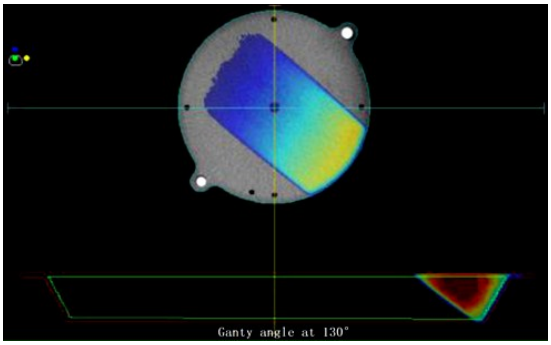


Figure 1. iBEAM® evo Couchtop EP simulated in the Monaco TPS (Gantry angle at 130°).

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RESULTS

Elekta Manual book declares the iBEAM® evo Couch top is in perfect synergy with modern radiation therapy techniques for its low dose attenuation (see table 1) and providing outstanding in situ imaging quality and minimizing artifacts, the dose influence almost can be neglected to the patient [16]. However, the attenuation we measured for the iBEAM® evo Couch top are higher (see figure 2) than the Elekta Company declared, which they declared are only concerned with a gantry angle of 180° and thus provide little indication of the magnitude of attenuation during oblique treatments. The most couch attenuation we measured for 6MV beam energy can be reach to 3.7%, almost one point five times of the Elekta Company declared couch attenuation. If we added 2% of the TPS calculated uncertainty [27], and then the total uncertainty can be almost reached to 6%, this value is far beyond the ICRU recommended that the accepted total uncertainty in the whole radiotherapy process amounts to 5% [28].

A comparison of the percentage deviation between the measurement dose and the Monaco calculated dose with and without the treatment couch modeling inserted were presented in table 2 -3. The results showed the iBEAM® evo Couch top model we have modeling in Monaco TPS with uniform ED 0.18g/cm3 or with 2 components fiber ED 0.5g/cm3 and foam core ED 0.1g/cm3 can decreased the measured and TPS calculated dose absolute average percentage deviation from the maximum 3.82% to be within 0.98% for different energies and calculated grid spacing. The uniform couch model is better than 2 components model, the maximum PD of the single beam are 1.96% and -2.3% for 10 MV at the gantry angle 160°, respectively, which within the AAPM Task Group 53 recommended acceptability criteria 2% for external beam dose calculations [27].

The film measured results at different depths were used by interpolation to generate a percent depth dose curves, and the results can be found in figure 3 showed a significant change in surface dose from 184 cGy to 383 cGy with the introduction of the treatment couch into the 6MV beam at the phantom depth 1mm, increased 109%. For 10MV and 18 MV beam energies when the treatment couch introduced the maximum surface dose increased 151% and 152.8% at depth 1mm, respectively. As the depth increased the treatment couch influence is decrease smaller and smaller, at the maximum dose depth for different energies, with or without treatment couch included there are almost without any change in the dose is delivered. Figure 2 also shows a dramatically surface dose increase from 45.9%, 35% and 29.2% of Dmax to 95.8%, 87.9% and 73.9% of Dmax for 6 MV, 10 MV and 18 MV beam, respectively, at the investigated 1mm depths, resulting from the couchtop bolus effect [29]. The depth of the maximum dose also changed from 15 mm to 5mm, and from 20 mm to 10 mm, and from 25 mm to 15 mm with the carbon-fiber tabletop for 6 MV, 10 MV and 18 MV, respectively.

The resulting DVHs for clinical case plans with and without couch model inserted are presented in figure 4 (doses were rescaled to the D50 of PTV equal to 30Gy). The D50 of the PTV without and with couch model included are changed from 30 Gy to 29.3 Gy, and therefore decreased by 2.4%. The D2 of the cord without and with couch model included changed from 30.4 Gy to 29.7, and decreased 2.3%. The reason of the dose decrease is caused by the couch absorption. Figure 5 illustrates the couchtop effects on skin and PTV doses. The figure 5 (a) and figure 5 (b) shows the 6 MV beams comparisons without and with couch model inserted VMAT plans. These depictions of beam attenuation effects are consistent with the results of DVH analysis and show the spatial areas of dose loss around the PTV target. And due to the buildup effect of the couch top, the surface doses increase to 29.0 Gy are almost the same as the prescription dose of PTV.

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Table 1. Elekta Company declared treatment couch dosimetric properties.

Field size:9.6x10.4cm; SSD 95 cm; d=5cm, Phantom: PMMA (solid water)		
Energy	6MV	10MV
Attenuation	2.4%	1.9%

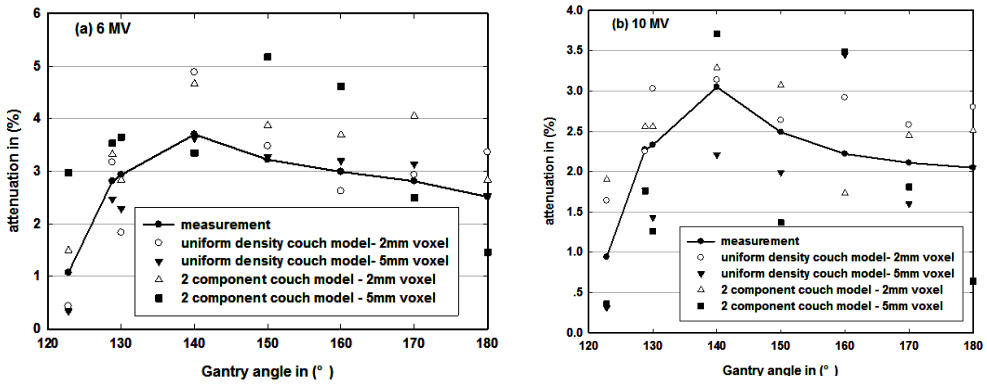


Figure 2. Couch attenuation of **(a)**6 MV and **(b)**10 MV beams with voxel grid spacing of 2 mm and 5 mm.

Table 2. Percentage division for 6MV and 10 MV beams with and without couch model included with grid size 2 mm (%).

Gantry Angle(°)	6MV			10MV		
	uniform	2 component	without couch	uniform	2 component	without couch
180	-1.06	-0.37	2.82	-0.94	-0.99	2.01
170	-0.31	-1.32	2.57	-0.65	-0.88	2.40
160	0.18	-0.76	3.26	-0.88	-0.03	1.16
150	-0.45	-0.70	3.20	-0.32	-1.11	1.22
140	-1.41	-1.03	3.27	-1.29	-0.78	1.97
130	0.94	0.06	2.26	-0.88	-0.77	1.73
128.8	-0.56	-0.56	2.00	-0.14	-0.83	2.69
[a]122.8	0.47	-0.46	1.08	-0.87	-1.49	0.81
Absolute Ave. PD	0.70	0.69	2.77	0.73	0.77	1.88

[a]Notes: The gantry angle of 122.8° which is the measured field isocenter exactly penetrate the couch edge is used for validate the couch position in the Monaco TPS in accordance with the measured couch setup, the calculated average value not include this value.

Table 3. Percentage division for 6MV and 10 MV beams with and without couch model included with grid size 5 mm (%).

Gantry Angle(°)	6MV			10MV		
	uniform	2 component	without couch insert	uniform	2 component	without couch insert
180	-0.24	1.19	4.63	0.76	-1.05	3.87
170	-0.56	0.44	4.45	-0.37	-0.54	3.08
160	-0.44	-1.57	4.77	-1.96	-2.30	2.86
150	-0.26	-1.90	2.07	0.48	-0.54	1.16
140	-0.15	0.49	3.02	-1.35	-0.20	4.77
130	0.44	-0.63	5.46	0.42	-0.14	-0.49
128.8	0.13	-0.63	2.38	-0.14	-0.54	1.22
[a]122.8	0.53	-1.81	-0.09	-0.09	-0.42	-0.03
Absolute Ave. PD	0.32	0.98	3.82	0.78	0.76	2.49

[a]Notes: The gantry angle of 122.8° which is the measured field isocenter exactly penetrate the couch edge is used for validate the couch position in the Monaco TPS in accordance with the measured couch setup, the calculated average value not include this value.

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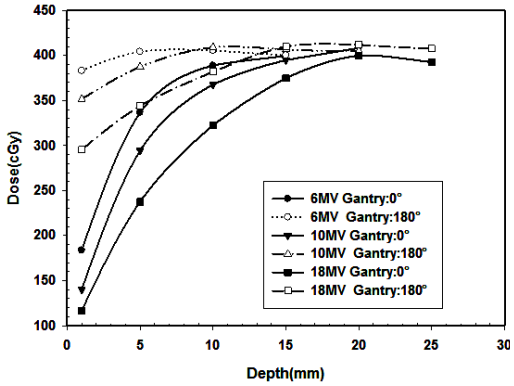


Figure 3. Film measured percent depth dose courves of with and withou iBEAM evo EP couchtop for 6MV, 10MV and 18MV beams.

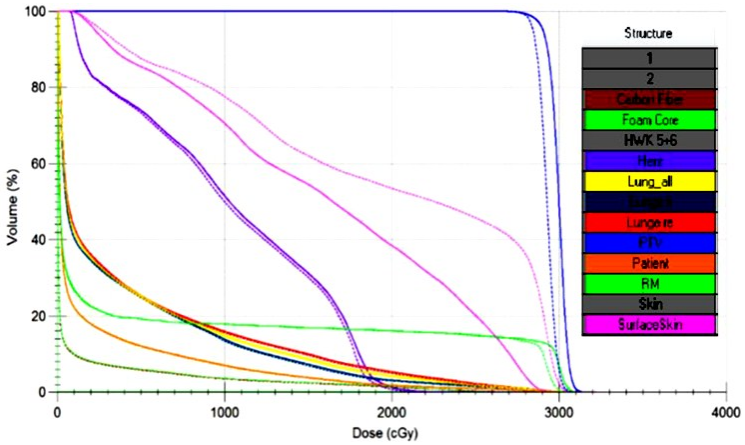


Figure 4. The resulting DVHs with and without couch model inclued. The solid line represents the DVH in the treatment plan without the couch. The dashed line represents the DVH with couch.

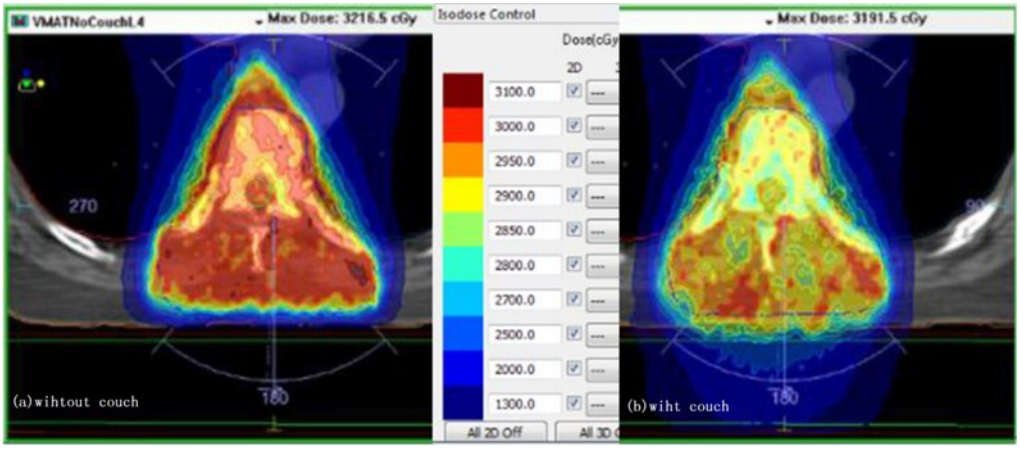


Figure 5. Dose differences of a VMAT dose distribution **(a)** without and **(b)** with couch inserted.(0.5 Gy isodose lines).

DISCUSSION

McCormack, *et al.* [30] proposed a "simple" solution using a correction factor based on the couch top attenuation to adjust the beam's MU to account for a fixed posterior oblique beam. This way can easily execute on conventional 2D and 3D-CRT planning, but for the IMAT and VMAT treatment modality they are delivered by a series of different weighted sub segments to achieve certain dosimetric objectives, it is almost impossible for them to use this ways. Therefore, simply adjusting the beam's MU based on the attenuation factor at iBEAM evo Couch top may result in an underestimated or overestimated dose distribution at the distal or proximal periphery of the beam [22].

In this study, we developed a method to model the treatment couch in Monaco TPS, and we have shown its effectiveness in account for the beam intersection with the couch top attenuation. From the figure 2 and tables 2-3 which can be known that for the iBEAM® evo Couch top EP couch model using the uniform couch model with ED 0.18g/cm^3, can obtained the best agreement between measured and Monaco TPS calculated doses. The maximum PD of the single beam was within 1.96% for 2 mm and 5mm grid space, this value are agreed to Venselaar *et al.* suggested of TPS the generally accepted tolerance is 2% for 2 mm grid space [31]. Our results are similar to the accuracy results achieved with different methods of couch incorporation in a commercial TPS [32]. And this results are a little better than van Prooijen *et al.* [11] reported the largest differences 2.3%, they

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are modeled the Sinmed Master couch in the Pinnacle TPS (Philips, v 8.0h) calculations using the adaptive convolution algorithm with calculation grid spacing 2.5 mm [11]. We found the values of fiber ED 0.6g/cm3 and foam core ED 0.1g/cm3 that resulted in the best agreement between measured and predicted dose were lower than Mihaylor *et al.* [33] reported 0.7 g/cm3 and 0.1 g/cm3 for fiber ED and foam core ED, respectively. And our results are almost the same as [17] demonstrated value to be fiber ED 0.55g/cm3 and foam core ED 0.03 g/cm^3 respectively. The results are observably lower than the Elakta quoted the electron density of 1.35 g/cm^3 for the iBEAM carbon fiber. However, smith *et al.* [12] studied the measured value of fiber density between 0.41g/cm^3 to 0.64g/cm^3 and they explained the discrepancy between quoted fiber density and measured fiber density to be due to the partial volume effect. In my opinions, one of the main reasons of the difference is that our modeled couch had an average couch fiber thickness of 8 mm instead of the 4 mm showed in Elekta manual book. Hence it is expected that to have the expected attenuation, the density of the fiber density would have to be lowered to compensate for the artificially elevated couch fiber thickness. This observation underscores the importance for an individual center to validate the couch modeling of every treatment unit before using it for patient treatment planning.

Traditionally, higher energy photon beams are used as radiation therapy for their ability to spare skin dose, due to the generation of electrons (Photo effect, Compton effect), the dose near the surface is less than a few centimeter below, while still administering effective dose to target regions below the skin. Based on the film measured dose at different depth (see figure 3), we can get that the iBEAM® evo EP couch top increased the skin dose about twofold for photon beam energies at 1mm depth which would be detrimental for the ability of treatments to avoid external radiation skin burns. For example, the values obtained without and with the carbon fiber tabletop at the 10 cm × 10 cm field for 6MV photon beam were 45.9% and 95.8%, respectively. The percent depth dose curve also shows a decrease in the depth of maximum delivered dose. Usually the depth of maximum dose delivery is considered to be 15 mm for a clinical 6MV beam, and the Gafchromic® film EBT3 measured dose delivered, without the couch included at the gantry 0°, a depth of maximum dose to be 15.1 mm. However when the beam perpendicular penetrated the iBEAM® evo EP Couch top at the gantry 180°, the depth of maximum dose delivery was measured as 0.53 cm, a decrease of 9.8 mm. Our findings are consistent with reports in the literature [34, 35], where it was demonstrated that Pinnacle CC algorithm reproduces ion-chamber measured doses in the build-up region to within 2% at depth beyond 0.5 cm, the couch carbon fiber couch water-equivalent thickness is 1.1 cm. As figure 4 and figure 5 demonstrated in a clinical setting this could lead to maximum dose to be delivered outside or off set target volume, especially for small treatment target volumes. This change in dmax lends itself to the possibility of inefficient and decreases the effective treatment procedures. The pattern of differences between calculations with or without couch at patient level treatment with VMAT was investigated, the graphs show the differential dose difference histograms for each volume. For PTV dose of D50 decrease as high as 2.3% and the volume of targets covered by the prescribed dose dropped from a clinically acceptable 50% to 7.4% for the couch model without and with included, respectively. These results cannot be clinically ignored and are in good agreement with previously published data in the literature [4, 9, 19, 36, 37].

Besides, the depth of the maximum dose decreased with the beam energy increased. From the figure 3 we also can get that the higher energy treatment beam of 18MV was affected less by the introduction of the treatment couch into the beam path, than the lower energy beam of 6MV. It is seen from the obtained results that the iBEAM® evo EP couch top have dramatically impact on the delivered surface dose, showing a significant increase in the surface dose and the skin-pairing effect was reduced. As it is shown in figures 3, our results for 6 MV, 10MV and 18 MV

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beam at the 10 cm × 10 cm field are in good agreement with other published data in the literature [12, 14, 15, 17, 29, 37]. To limit the loss of skin sparing due of couch top, Mihaylov *et al.* [34, 38] has suggested using mixed beams that is using higher photon energies for the beam traversing the couch top. However, we should be noted that the disadvantage of this proposal is using the high photon energy in IMRT may introduce neutron production. Insufficient compensation for these uncertainties leads to target underdosing and overdosing of nearby OARs, whereas overcompensation for uncertainties leads to unnecessary irradiation of normal tissue and constraints in treatment planning. By the couch included the Monaco treatment planning system calculated percent deviations within a reasonable 2% range for the iBEAM® evo Couch top EP, could compensate for the differences between planned and delivered dose. Because the calculated space volume will be increased when the couch model was included. The one disadvantage of the couch model inserted is increased the Monaco TPS calculated time [22]. The calculated time without and with couch model included are 32min and 52min for calculated grid space 2mm, respectively, almost increased 63%.

CONCLUSION

The iBEAM® evo EP couch top would generally be used during treatments conducted on the abdomen and pelvis sites of a patient. As such, in these sites the interference of this section of the couch must be fully accounted for, because such cases are more likely to need to reach a larger depth of penetration before delivering maximum dose. The couch top attenuation and the buildup effects would be most pronounced. We have characterized the dose difference due to couch attenuation of the iBEAM® evo EP couch top through detailed angular measurements with different energies, and demonstrated that for VMAT, an 2.3% dose difference could be expected for vertebral body metastasis cases if the treatment couch was not included in the planning system. Our results further indicate that the iBEAM® evo Couch top EP can approximately double the surface dose, relative to the maximum delivered dose, on the skin of the patient. This buildup interference by the treatment couch is most prevalent for lower treatment energies, which should be taking more notice. The implementation of such couch model will ensure confidence that each patient will receive the optimal treatment as planned and that no errors will occur in the clinical implementation of the treatment plan delivering though the treatment couch.

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***Conflicts of interest*:** *Declared none.*

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