

# Treatment Couch Modeling in the Treatment Planning System Eclipse

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## Abstract

**Purpose:** Previously in treatment planning systems (TPS) the treatment couch was expected to be made out of air-equivalent material due to the used material (Carbon). Some studies have already shown that the treatment couch cannot be neglected during treatment planning. Nowadays the manufacturer of TPS implemented the feasibility to insert treatment couch structures. This study aimed to find the correct modeling of the treatment couch parameters in the TPS Eclipse.

**Method:** The Varian Exact Treatment Couch consists of a carbon board (length 2.5 cm) and two moveable rails (length 8.5 cm) underneath. The treatment couch can be modeled in TPS by changing the Hounsfield units (HU) for each part of the treatment couch. For low and high photon energies the attenuation of the treatment couch was measured at a Clinac 2300 C/D and in the TPS the attenuation of the treatment couch model was determined for different sets of HU values. Measured and calculated attenuations were compared to each other.

**Results:** Minimum aberration between the calculated and measured attenuation of treatment couch were found for the HU values of -750 HU for the carbon plate, -995 HU for the filling of the carbon plate and 225 HU for the rails. Additionally it was found that the attenuation is dependent on the gantry angle. Like expected the highest attenuation was found in the region of the rails underneath the treatment couch.

**Conclusion:** For Varian Exact Treatment Couch the HU values should be adjusted to -750 HU for the carbon plate, -995 HU for the filling of the carbon plate and 225 HU for the rails. The same HU set can be used for low and high photon energies. With the correct set of HU values the treatment couch is modeled correctly in the TPS Eclipse.

**Keywords:** Radiation therapy; Treatment planning; Couch structures; Attenuation

## Introduction

The treatment couch and some of the positioning devices of patients receiving radiotherapy treatment are made of a material (carbon) which has low attenuation properties for the photon energies used in the radiotherapy. Previous investigations showed the suitability of carbon fiber tabletops in radiotherapy and their very low attenuation properties for a range of X-ray energies and field sizes (De Ost et al., 1997; Higgins et al., 2001; Meara and Langmack, 1998). The Carbon treatment couch is designed to minimize the potential blocking of the radiation treatment beam for conventional treatment techniques (Buckle, 2005; Meyer et al., 2001; Muthuswamy, 1999; Spezi et al., 2008). Some studies have shown that the treatment couch is not negligible during treatment planning process whereas the dose delivery is performed with treatment couch (Myint et al., 2006; Poppe et al., 2007; Spezi and Ferri, 2007; Vieira et al., 2003).

The effect of the treatment couch to the dose distribution depends on the gantry angle. The effect is larger for posterior beam angles (McCormack et al., 2005). The attenuation increased from 2% for beam angles as the gantry approaches the plane to 9% for posterior beam angles. This could have serious implications regarding dose to the treatment volume for treatments requiring posterior oblique angles of incidence with a possible correction factor necessary in monitor unit calculations (McCormack et al., 2005). Side bars or other design features specific of each carbon fiber tabletop disturbed the dose distribution at the isocenter at specific gantry angles (Gillis et al., 2005; Munjal et al., 2006).

It has also to be taken into account that the skin dose increased due to the carbon couch top. The treatment couch operates as a buildup (Meara and Langmack, 1998). The carbon fiber tabletop

significantly decreases the skin-sparing effect. The dosimetric effect of the tabletop may be higher, especially for the intensity-modulated radiation therapy depending on the beam orientation (Meydanci and Kemikler, 2008). The potential for dose delivery errors or increased whole-body dose should be carefully considered by newest delivery technologies (Galvin et al., 2004).

Due to some studies recommending the consideration of the treatment couch during the treatment planning process investigations are made to construct the treatment couch in the treatment planning system. The appropriate contouring together with relevant density information for the contours is sufficient for adequate modeling of carbon fiber supporting devices by modern commercial treatment planning systems and can reduce the differences between the dose calculated without consideration of the treatment couch and the dose calculated with consideration of the constructed treatment couch (Mihaylov et al., 2008).

Using the treatment planning system Eclipse Version 8.9 from Varian Medical Systems (Helsinki, Finland) in combination with the Anisotropic Analytical Algorithm (AAA) the treatment couch

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structures can be easily inserted. The AAA is a 3D pencil Beam convolution/superposition algorithm that uses separate Monte Carlo derived modeling for primary photons, scattered extra-focal photons and electrons scattered from the beam limiting devices (Ulmer et al., 1995; Ulmer et al., 2005). The treatment couch can be considered in optimization process and dose distribution calculation. The aim of this study was to find the correct modeling parameters of the treatment couch (Varian Exact Couch) in the treatment planning system Eclipse. Therefore measurements at Varian Clinac 2300 C/D and calculation in treatment planning system Eclipse were made to determine the attenuation of the treatment couch for low and high photon energies. Both attenuations were compared to each other and the modeling of treatment couch was adapted till measured and calculated dose fitted together.

## Methods and Materials

### Setup for measurements

For the measurements of attenuation of the treatment couch a cylindrical phantom made of PMMA (Polymethylmethacrylat PMMA) was set up on the treatment couch. The reading of an ionization chamber with an active measuring volume of 0.3 cm<sup>3</sup> (Farmer chamber, PTW, Freiburg, Germany) was determined for the gantry angles between 0° and 360° (every 5°). The measurements were carried out for both photon energies, 6 MV<sub>photons</sub> and 20 MV<sub>photons</sub>, with a field size of 10 cm x 10 cm. The ionization chamber was at source to detector distance (SDD) of 100 cm and cylindrical surrounded by 10 cm PMMA. The reading of ionization chamber was determined three times for middle position and external position of rails underneath the treatment couch (Figure 1). 100 monitor units (MU) were delivered.

### Treatment couch

The Varian Exact Treatment Couch consists of a carbon plate with a thickness of 2.5 cm and two carbon rails beneath the carbon plate for stabilization purposes with a height of 8.5 cm. The couch top is made of carbon shell with a length of 1.0 mm at the top and of 2.5 mm at the bottom filled with foam. The rails are made of a shell with a length of about 10 mm filled with air. The moveable rails can be moved in every position underneath the treatment couch. There are no fixed positions for the reproducibility of the position of the rails. In practice the positions in the middle and outer most are used.

### Calculation with TPS eclipse

In TPS Eclipse version 8.9 from Varian Medical System the treatment couch from the same manufacturer can be inserted in every CT-dataset (CT = computertomography) of a patient or phantom. The HU values of each part of treatment couch can be typed in. With these HU values the attenuation of treatment couch is assessed. For the treatment couch the manufacturer set -300 HU for the Carbon plate, -1000 HU for the foam inside the Carbon plate and 200 HU for the rails as default. To determine the correct HU values of each

part of treatment couch the attenuation of the treatment couch at a Clinac 2300 C/D was determined. The same setup of cylindrical phantom on treatment couch was used in TPS and the attenuation of the treatment couch in TPS was determined. Therefore a photon field with a field size of 10 cm x 10 cm for both photon energies, 6 MV<sub>photons</sub> and 20 MV<sub>photons</sub>, was set up on the CT-scan of the PMMA phantom with ionization chamber inserted and the mean dose to the active volume of the ionization chamber was determined for the gantry angles between 0° and 360° (every 5°). The isocenter of the photon field was set at the middle of the cylindrical phantom. The dose distribution was calculated with the anisotropic analytical algorithm AAA with a grid size of 2 mm x 2 mm x 2 mm. The treatment plan was normalized to 100 MU.

### Calculation of attenuation of treatment couch

The attenuation of treatment couch was calculated as ratio of measured value with treatment couch M<sub>couch</sub> to measured value without treatment couch M<sub>no couch</sub>:

$$\text{attenuation} = \frac{M_{\text{couch}}}{M_{\text{no couch}}} \cdot 100\% \quad [1]$$

For the measurements in TPS the measured values with and without treatment couch could be determined for all gantry angles. For the measurement at the Clinac 2300 C/D the cylindrical phantom was setup on treatment couch. To calculate the attenuation of treatment couch the measured value of 0° was used for the measured value without treatment couch due to the cylindrical setup.

### Analysis

Both, the attenuation calculated in TPS (calculated attenuation) and calculated with the measurements at Clinac 2300 C/D (measured attenuation) were compared to each other to find the minimum aberration. For the set of HU values with minimum aberration the best modeling of treatment couch in TPS is given.

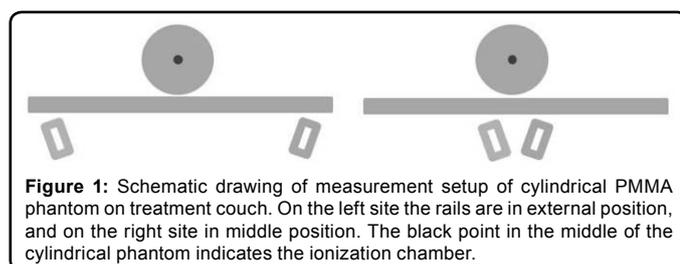
### Uncertainty budget

Since the ratio of measured attenuation to calculated attenuation was considered as the end result, the following sources contributing to the overall uncertainty of the result were identified:

- Ionization chamber measurement method
- Dose calculation of the treatment planning system
- Positioning of the cylindrical phantom on treatment couch

In our study, the uncertainty components for ionization chamber measurement method had to be taken into account due to positioning of cylindrical phantom using the isocentric laser system in treatment room, the response of ionization chamber reading and an additional component for directionally response of ionization chamber by rotation of the chamber around its axis by more than 10°. As a result, an uncertainty of the measured values with the Clinac 2300 C/D of 2.2% was obtained. The components of the combined uncertainty for the measured values with TPS are shown in Table 1.

For the accuracy of the dose calculation, the manufacturer specifies 1.0% for unblocked photon fields. The uncertainty of the treatment machine's basic data measurements had to be taken into consideration within 2 mm. The consideration of 2 mm contained the exact positioning of the ionization chamber during basic data measurements for the TPS before clinical operation. However, the combined relative standard uncertainty of the measured values with TPS was only 1.0%. The different contributions are listed in Table 1. All uncertainties are stated as k = 1 (1r) standard uncertainties.



**Figure 1:** Schematic drawing of measurement setup of cylindrical PMMA phantom on treatment couch. On the left site the rails are in external position, and on the right site in middle position. The black point in the middle of the cylindrical phantom indicates the ionization chamber.

Calculated values		Measured values	
Components for calculated values	Relative standard uncertainties	Components for measured values	Relative standard uncertainties
Dose calculation of the treatment planning system	1.0%	Positioning of cylindrical PMMA phantom	0.3%
Basic data measurements	0.3%	Response of ionization chamber	2.0%
		directionally response of ionization chamber by rotation of the chamber around its axis by more than 10°	0.1%
<b>Total</b>	<b>1.0%</b>		<b>2.2%</b>

Table 1: Uncertainty budget.

Treatment couch parts	Set Default	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
Carbon plate	-300 HU	-280 HU	-700 HU	-700 HU	-700 HU	-800 HU	-750 HU
Filling	-1000 HU	-800 HU	-960 HU	-960 HU	-960 HU	-960 HU	-995 HU
Rails	200 HU	200 HU	100 HU	200 HU	250 HU	100 HU	225 HU

Table 2: HU values for the different parts of treatment couch. The Varian exact treatment couch consists of a Carbon plate with a filling and of two rails underneath the Carbon plate for stabilization purposes.

Middle position of rails				
	6 MV <sub>photons</sub>		20 MV <sub>photons</sub>	
	Carbon couch top	Rails	Carbon couch top	Rails
Set Default	much too high	good	much too high	good
Set 1	much too high	good	much too high	good
Set 2	too high	too low	too low	good
Set 3	too high	good	good	good
Set 4	too high	good	too low	too high
Set 5	too low	too low	good	good
Set 6	good	good	good	good
External position of rails				
	6 MV <sub>photons</sub>		20 MV <sub>photons</sub>	
	Carbon couch top	Rails	Carbon couch top	Rails
Set Default	too high	good	much too high	good
Set 1	too high	good	much too high	good
Set 2	good	too low	too high	good
Set 3	good	good	good	good
Set 4	good	too high	good	good
Set 5	too low	too low	too low	too low
Set 6	good	good	good	good

Table 3: Results of the comparison between measured and calculated attenuation for the subsumed gantry angles. Aberration of <2.2% indicates a good agreement between calculated and measured attenuation, a positive aberration >2.2% too low HU values and a negative attenuation >2.2% too high HU values.

	Mean difference	Range
Set Default	0.84% ± 0.15%	-3.63% to 8.43%
Set 1	1.08% ± 0.15%	-2.60% to 9.46%
Set 2	0.35% ± 0.32%	-6.63% to 6.66%
Set 3	0.21% ± 0.17%	-6.11% to 8.83%
Set 4	0.25% ± 0.24%	-5.40% to 4.03%
Set 5	0.57% ± 0.40%	6.16% to 5.72%
Set 6	0.15% ± 0.13%	-2.02% to 1.96%

Table 4: Mean difference between measured and calculated attenuation of treatment couch, its standard uncertainty and its range. The mean difference was calculated for both photon energies and both positions of rails.

## Results

To determine the attenuation measurements were made at a Clinac 2300 C/D and calculations were made in TPS Eclipse. The measured values were determined for rails in middle and external position, for both photon energies, 6 MV<sub>photons</sub> and 20 MV<sub>photons</sub> and for gantry angles from 0° to 360° (every 5°). Beginning with the default settings of HU values given by manufacturer the correct HU values were approached. In the end, seven HU-sets for Carbon plate and its filling and for rails were used till the optimal modeling of treatment couch was reached. The HU-sets are listed in Table 2.

For easy comparison of attenuation the measured values of the gantry angles were subsumed which were affected by the Carbon plate and by Carbon plate and rails. Gantry angles from 120° to 150° and from 210° to 240° were subsumed for Carbon plate attenuation, rails in middle position and gantry angles from 140° to 220°, rails in external position, respectively. For Carbon plate and rails gantry angles from 120° to 135° and from 225° to 240° were subsumed, rails in middle position and gantry angles from 160° to 170° and from 190° to 200°, rails in external position, respectively. In Table 3 the results of the comparison between measured and calculated attenuation for the subsumed gantry angles are listed. An aberration smaller than

2.2% (within measurement accuracy, Table 1) was defined as 'good agreement' for the HU values used, a positive aberration larger than 2.2% as 'too low' and negative aberrations larger than 2.2% as 'too high'. Much too high HU values for Carbon plate were found for Set Default and Set 1 (aberration > 50% to the measured values). For Set 2, Set 3 and Set 4 the aberration was between 2.2% and 5%. For these sets the HU values were a little bit too high for Carbon plate. Aberration larger than 5% was found for Set 5, except for photon energy of 20 MV<sub>photons</sub> and rails in middle position. For Set 5 the HU values were set too low for Carbon plate. A good agreement for all measurements was found for Set 6 and therefore a good modeling of treatment couch top in TPS. For Carbon plate and rails aberrations smaller 2.2% were found mainly for photon energy of 20 MV<sub>photons</sub>. For photon energy 6 MV<sub>photons</sub> the HU values were set too low for Set 2 and Set 5. Set 4 showed too high HU values for photon energy 6 MV<sub>photons</sub> and external position of the rails, as well as for 20 MV<sub>photons</sub> and middle position of the rails. Figure 2 shows the measured and calculated attenuation of treatment couch for both photon energies, for middle and external position of the rails. For Carbon plate the HU values were much too high for Set Default und Set 1, too low for Set 5, a little bit too high for Set 2, Set 3 and Set 4 and finally optimal for Set 6. For Carbon plate and rails the HU values were too low for Set 2 and Set 5, too high for Set 4 and optimal for Set Default, Set 1, Set 3 and Set 6 (Figure 2).

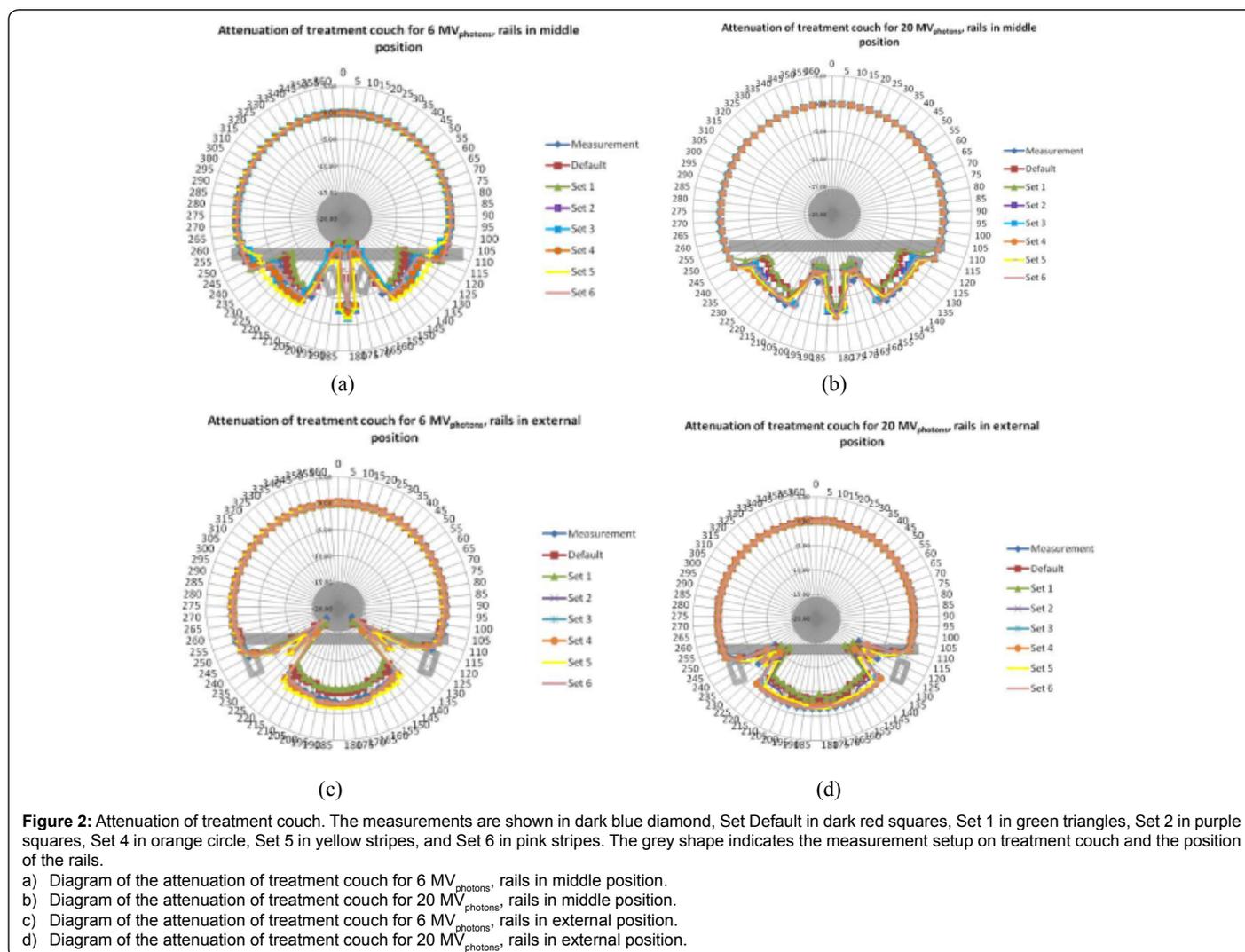
In Table 4 the mean difference between measured and calculated attenuation is listed for both photon energies, for middle and external position of the rails. A minimum was found for Set 6 with 0.15% with its standard uncertainty of 0.13% and the range from -2.02% to 1.96%. The best agreement between measured and calculated attenuation was found for Set 6 (Figure 2 and Table 4). In Figure 2 it can also be seen that the attenuation increased in the region of the rails and is less in the region of the Carbon plate.

To verify the results a CT scan was made of Carbon plate and rails before installation. The HU values could be verified to -750 HU for Carbon plate, -995 HU for its filling and 225 HU for rails.

## Discussion

The aim of this study was to model the treatment couch in TPS by finding the optimal HU values for each part of treatment couch. By typing in the optimal HU values the attenuation of treatment couch is correctly considered during treatment planning.

The aberration and therefore the HU values between measured and calculated attenuations of Set Default and Set 1 were too high. Beginning with the study of Vanetti et al. [20], who found out HU values of -700 HU for Carbon plate and -960 HU for its filling for another type of treatment couch, -700 HU was used for Carbon plate



and -960 HU for its filling. For the rails HU values of 100 HU, 200 HU and 250 HU were set to find out the optimal modeling. The aberration between measured and calculated attenuation for Carbon plate and its filling for the Sets 2, 3 and 4 was still too high and therefore the HU values. For the rails an HU value of 100 HU turned out to be too low, which could be verified by Set 5. For the HU values of 200 HU and 250 HU for the rails good results for some measurements and a little bit too high aberrations for some measurements were found, respectively. In the end 225 HU for the rails for Set 6 were taken and turned out to be optimal modeling. For the Carbon plate and its filling less HU values were taken for Set 5 and it was found that the HU values were too less. Therefore Set 6 was set to -750 HU and -995 HU for Carbon plate and its filling and turned out to be optimal modeling.

Carbon is a material which has low attenuation properties for the photon energies used in the radiotherapy (Meyer et al., 2001; Muthuswamy, 1999; Spezi et al., 2008). Therefore carbon is utilized for patient treatment couch and positioning devices of patients. Poppe et al. (2007); Myint et al. (2006) showed that the treatment couch is not neglectable during the calculation of dose distribution (Meara and Langmack, 1998; Myint et al., 2006; Poppe et al., 2007). In agreement with these statements we found in our analysis that the mean attenuation of Carbon plate was between 1.49% and 3.20% dependent on photon energy and gantry angle. In the region of rails the attenuation was higher. The rails are moveable and can mostly be moved out of the treatment field. This is possible for most 3D conformal treatment techniques with few treatment fields and gantry angles. For IMRT using seven to nine treatment fields and gantry angles, as well as for arc treatments or volumetric modulated arc treatment it is mostly not possible to move the rails out of treatment fields. For dynamic treatments it is necessary to consider the treatment couch during treatment planning to apply the correct dose to patient. The tumor control probability increases significantly if the uncertainty of applied dose can be minimized by 2%. The attenuation of rails is 8.83% to 17.01% dependent on photon energy, position of rails underneath the treatment couch, gantry angle and therefore irradiated volume of the rails.

Mihaylov et al. (2008) showed in their study that contouring of treatment couch and attenuation information is necessary for the correct modeling of treatment couch in TPS to minimize the difference between calculated and applied dose (Mihaylov et al., 2008). Our results showed that the treatment couch can be correctly modeled in the TPS Eclipse. However, the default attenuation has to be corrected by typing in the correct HU values for different couch parts. One set for low and high photon energies is adequate for the correct modeling of treatment couch in TPS, just as described by Vanetti et al. (2009). In their study they analyzed the IGR7 couch top from Varian Medical System for photon energies of 6 MV<sub>photons</sub> and 15 MV<sub>photons</sub>. They showed that it is possible to verify the attenuation of treatment couch given from manufacturer as default using easy measurement setup. Due to our study we support this statement. However, it takes its time to find out the correct HU values and therefore the correct attenuation of treatment couch in TPS. Some sets of HU values for the different parts of treatment couch have to be tested. A fast way is to use a CT scan of treatment couch to verify the correct HU values of treatment couch.

McCormack et al. (2005) examined the magnitude of the effect over a range of posterior oblique gantry angles using a cylindrical solid water phantom containing an ionization chamber placed isocentrically. They found that a 6 MV photon beam with a field

size of 10 x 5 cm was attenuated significantly as the gantry angle approached the plane of the couch from 2% at normal incidence and reaching 9% attenuation at angle of incidence 70 degrees. This could have serious implications regarding dose to the treatment volume for treatments requiring posterior oblique angles of incidence with a possible correction factor necessary in monitor unit calculations like breast cancer treatment and IMRT treatments with its many treatment fields and gantry angles. In our study the attenuation increased from 1.49% to 3.20% for Carbon table top and from 8.83% to 17.01% for rails dependent on photon energy and gantry angle.

The HU values for correct consideration of attenuation of treatment couch during treatment planning have to be typed in manually after inserting treatment couch in patient's CT dataset. There is no generalized possibility in administration to type in the correct HU values for each part of treatment couch. Due to the manually correction of HU values after inserting treatment couch can cause errors. Therefore the manufacturer is asked to provide a possibility for entering the verified HU values in administration.

## Conclusion

The Varian Exact Couch can be modeled adequately in the TPS Eclipse. However, the HU values and therefore the attenuation have to be corrected manually for each patient. For Carbon plate an HU value of -750 HU, for its filling of -995 HU and for the rails of 225 HU have to be used for correct consideration of attenuation of treatment couch during treatment planning. For low and high photon energy one set of HU values can be used for correct modeling of treatment couch attenuation. The manufacturer is asked to provide a possibility for generalized entry of the verified HU values in administration to minimize the error source due to manually correction of HU values after inserting treatment couch to patients CT dataset.

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