Original

An Update of Couch Effect on the Attenuation of Megavoltage Radiotherapy Beam and the Variation of Absorbed Dose in the Build-up Region

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ABSTRACT

Purpose: Fiber carbon is the most common material used in treating couch as it causes less beam attenuation than other materials. Beam attenuation replaces build-up region, reduces skin-sparing effect and causes target volume under dosage. In this study, we aimed to evaluate beam attenuation and variation of build-up region in 550 TxT radiotherapy couch.

Materials and Methods: In this study, we utilized cylindrical PMMA Farmer chamber, DOSE-1 electrometer and set PMMA phantom in isocenter of gantry and the Farmer chamber on the phantom. Afterwards, the gantry rotated 10°, and attenuation was assessed. To measure build-up region, we used Markus chamber, Solid water phantom and DOSE-1 electrometer. Doing so, we set Solid water phantom on isocenter of gantry and placed Markus chamber in it, then we quantified the build-up region at 0° and 180° gantry angels and compared the obtained values.

Results: Notable attenuation and build-up region variation were observed in 550 TxT treatment table. The maximum rate of attenuation was 5.95% for 6 MV photon beam, at 5×5 cm^2 field size and 130° gantry angle, while the maximum variation was 7 mm for 6 MV photon beam at 10×10 cm^2 field size.

Conclusion: Fiber carbon caused beam attenuation and variation in the build-up region. Therefore, the application of fiber carbon is recommended for planning radiotherapy to prevent skin side effects and to decrease the risk of cancer recurrence.

Keywords

Beam Attenuation, Carbon Fiber, Couch Insert, Surface Dose, Megavoltage Radiotherapy

Introduction

The increasing use of carbon fiber in treatment tables is due to its favorable characteristics such as high beam transmission, physical resistance, low specific density, light weight and high specific strength. These characteristics of carbon fiber make it appropriate to be used in radiotherapy couch. Previously used materials such as steel have about 40% potential of attenuation due to their high density.

Despite the desirable characteristics of carbon fiber tabletops, beam attenuation by couch inserts can be significant. Not accounting for the increased attenuation can result in under-dosage of the target volume. Beam absorption by the tabletop can also be significant; thus, increased patient skin dose can be observed as skin toxicity [1]. Photon beam attenuation properties of carbon fiber couch inserts have been studied by several researchers [2-9].

In a study conducted by Higgins et al., a relative increase of 375% in the surface dose with 8 MV photon beams was observed when a carbon fiber insert panel (SinMed BV) was added to a 10×10 cm² field size [3]. Moreover, McCormack et al. measured an increase in beam attenuation ranging from 2.0% at 0° gantry angle to 8.7% at 70° with the studied SinMed BV Posisert carbon fiber couch insert [4]. However, in a study by Poppe et al., an attenuation of 2.7% at 0° gantry angle with a RM2/4 tabletop at a15×15 cm² field size was observed [5]. The attenuation properties of an ExacTrac couchtop (in this study, a Brainlab couchtop was used) were measured with 6 MV and 18 MV photon beams by Mihaylov et al. With 6 MV, they determined the beam attenuation to be 3.2% and 8.6% with beam incidence angles of 0° and 75°, respectively [9].

Material and Methods

In this study, performance measurement of Siemens couch (550 TxT) and PRIMUS+ accelerator with 6 MV and 18 MV photon beams at Reza Radiotherapy and Oncology Center were performed in two steps:

Couch attenuation measurement

Beam source-axis distance (SAD) for in-air and in-phantom monitors in all steps was 100 cm. The PMMA phantom was aligned longitudinally with the treatment table and the isocenter was set at the center of the chamber.

a) For measuring beam without couch attenuation, we set Farmer chamber (PTW Farmer) in isocenter of the cylindrical phantom. A reference value was determined with a direct anterior beam (0° gantry angle), then beam was evaluated at 45° and 90° gantry angles (Figure 1). The three field sizes of 5×5 cm², 10×10 cm², and 20×20 cm² were exposed to 6 MV and 18 MV photon energies, and the obtained values from PTW Unidose electrometer were recorded.

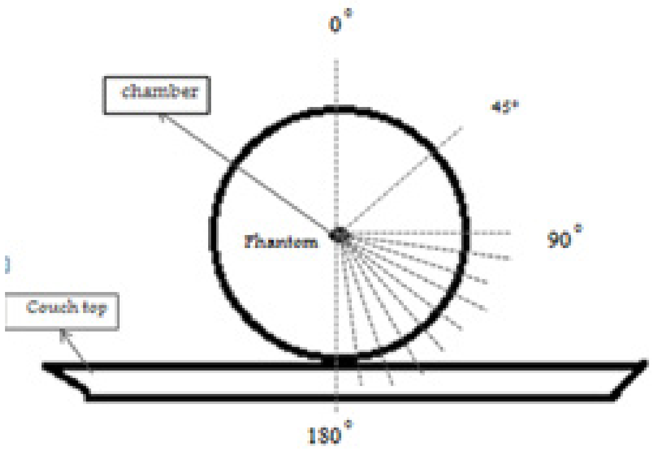

Figure 1: Beam attenuation measurement

b) For measuring beam with couch attenuation, we set Farmer dosimeter (PTW farmer) in phantom, and exposed 6 MV and 18 MV photon energies to the three field sizes of 5×5 cm², 10×10 cm² and 20×20 cm². Afterwards, the full gantry rotated about the isocenter, and measured beam in every 10° gantry angles between 90° and 180° angles (Figure 1). Subsequently, the final record values of Unidose electrometer were compared with and without couch value to obtain attenuation percentage.

Measurement of build-up region

a) We used parallel-plate chamber (Markus chamber, for dosimetry) and Solid water phantom at 100 cm SAD with monitor unit of 100 MU. We placed 15 cm Solid water slab under phantom to eliminate back-scattering effect, and for measuring build-up region, we recorded Unidose electrometer value at two gantry angles of 0° (Figure 2) and 180° (Figure 3) in two field sizes of 10×10 cm² and 20×20 cm². The diameter of solid water phantom increased with placing plate of different thicknesses on dosimeter, in each step that transmission beam was evaluated until reaching depth of the build-up region. We compared the obtained values to achieve couch effect on variation of

Figure 2: Build-up region measurement (without couch)

build-up region.

Results

Beam attenuation of 550 TxT treatment table

Figure 3: Build-up region measurement (with couch)

was measured in three fields with 6 MV and 18 MV photon energies. The results of 550 TxT couch attenuation are shown in Table 1. The first column shows gantry angle, the first row represents energy and the second row shows

Table 1: 550 TxT couch attenuation at 6 and 18 MV and three field sizes [(5×5), (10×10) and (20×20)] cm^2

Gantry angle	6 MV			18 MV		
	5×5 cm^2	10×10 cm^2	20×20 cm^2	5×5 cm^2	10×10 cm^2	20×20 cm^2
0	0	0	0	0	0	0
45	0	0	0	0	0	0
90	0	0	0	0	0	0
100	0.39	0.34	0.38	0.38	0.41	0.45
110	0.29	0.43	0.23	0.38	0.48	0.19
120	5.89	5.69	5.18	4.09	4.05	3.67
130	5.95	5.69	4.95	4.01	4.05	3.41
140	5.05	4.84	4.02	3.39	3.28	2.82
150	4.56	4.31	3.71	3.16	3.07	2.62
160	4.36	4	3.48	3.01	2.86	2.49
170	4.06	3.7	3.17	2.7	2.58	2.36
180	3.86	3.62	3.09	2.62	2.41	2.21

MV=Mega Volt, cm=centimeter

field size. The smallest field size and the lowest beam energy demonstrated the greatest beam attenuation for 550 TxT treatment table. Couch attenuation was 5.95% at 5×5 cm^2 field size and 130° beam angle, with 6 MV photon energy. Couch attenuations in 550 TxT treatment table at the three field sizes of 5×5 cm^2, 10×10 cm^2 and 20×20 cm^2 with 6 MV and 18 MV photon energies are presented in Table 1 and Figures 4 and 5. Comparison of surface dose in the two field sizes of 10×10 cm^2 and 20×20 cm^2 with the two photon energies of 6 MV and 18 MV is exhibited in Tables 2, 3, 4 and 5 and Figures 6, 7, 8, and 9.

Discussion

One of the most important advantages of megavoltage beam in radiotherapy is its skin-sparing effect. The use of megavoltage beams in radiotherapy has reduced the incidence rate of skin erythema, fibrosisand desquamation, as compared to the orthovoltage beams [10, 11]. Couch attenuation replaces build-up region and reduces skin-sparing effect; however, using carbon fiber for radiotherapy couch, skin reaction increases in clinical practices when the beam passes through treatment couch [12]. The heightened beam attenuation and surface dose by the treatment radiotherapy couch is important to prevent under-dosage of the target volume and skin reactions. Photon beam attenuation and incremented surface dose caused by radiotherapy couches have to be assessed for Siemens ZXT couch [13].

The photon beam attenuation of several couch tops has been studied in a number of studies. Njeh et al. carried out a study to measure beam attenuation by the Brain lab imaging couch top [14]. They found the maximum attenuation to be 8.3% at a gantry angle of 120°. Moreover, an attenuation of 3.4% at 180° beam angle with 6 MV photons and a field size of 10×10 cm^2 was found. The 6 MV photon beam measurements of Vanetti et al. of the Varian Exact IGRT couchtop (the thinner part) suggested attenuation of 2.3% and 3.1% at gantry angles of 180° and 135°, respectively [15]. Additionally, Butson et al. assessed the skin-dose increase with a Varian carbon fiber grid couchtop. The skin dose increased from 27% to 55%, with a direct posterior 6 MV beam and a field size of 10×10 cm^2 [14].

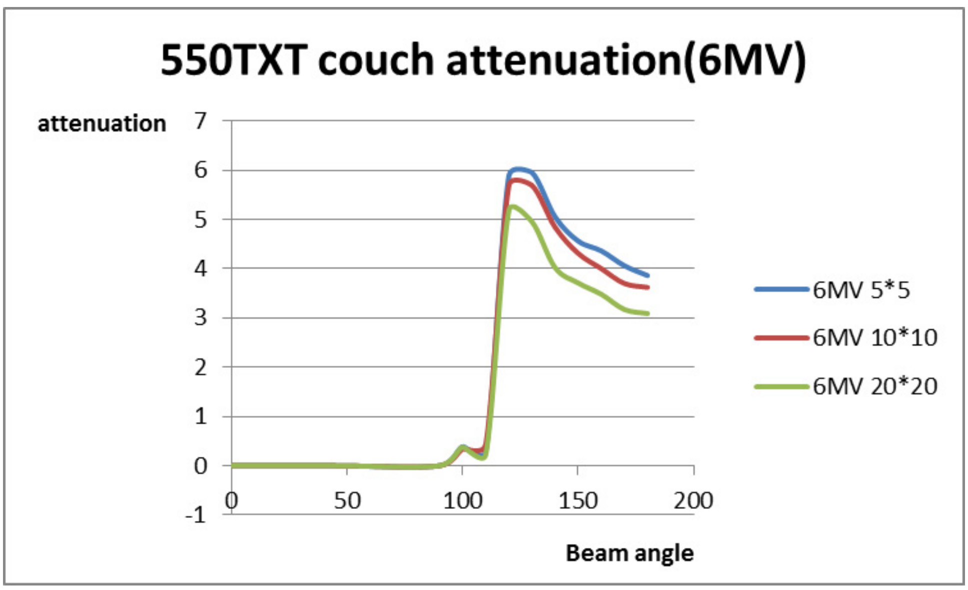

Figure 4: 550 TxT couch attenuation in 6 MV energy and three field sizes [(5×5), (10×10) and (20×20)] cm^2

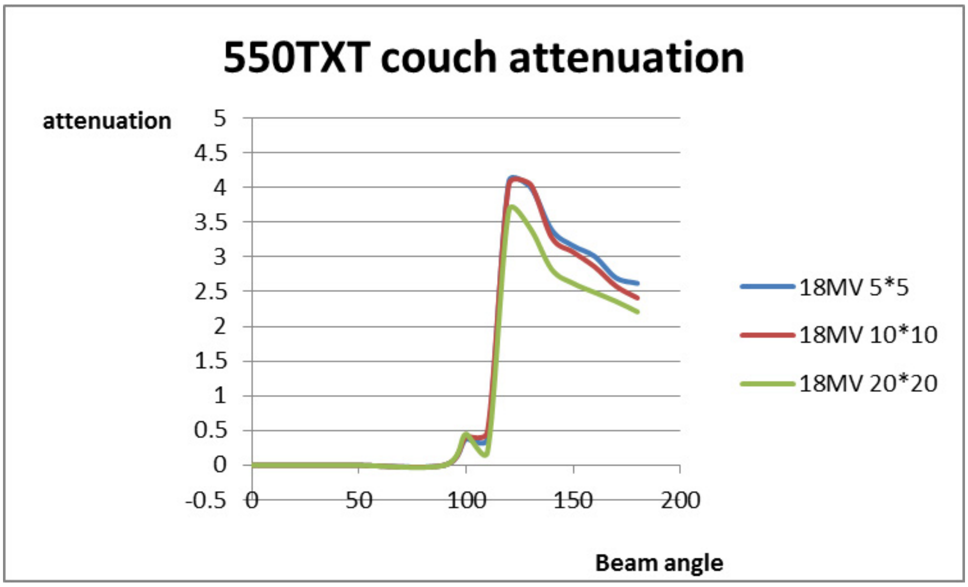

Figure 5: 550TxT couch attenuation at 18 MV energy and three field sizes [(5×5), (10×10) and (20×20)] cm^2

Table 2: Comparing buildup region with and without 550 TxT couch at 18 MV and 10×10 cm^2 field size

18MV (10×10 cm²)			
Depth (mm)	PDD (10×10cm2, without couch)	Depth (mm)	PDD (10×10cm2, with couch)
0	28.57	0	76.06
1	38.75	1	79.27
3	54.25	3	84.11
5	65.9	5	87.95
7	74.49	10	94.5
10	83.99	12	96.07
12	88.24	14	97.55
14	91.75	16	98.25
16	94.53	18	99.21
18	96.48	20	99.56
20	97.87	22	99.82
24	99.35	24	100
26	99.9	25	99.91
28	100	26	99.91
29	100	27	99.91
30	99.9		
31	99.81		

MV=Mega Volt, mm= millimeter

Table 3: Comparing buildup region with and without 550 TxT couch at 18 MV and 20×20 cm² field size

18MV (20×20 cm²)			
Depth (mm)	PDD (without couch)	Depth (mm)	PDD (with couch
0	40.06	0	83.28
1	46.91	1	85.69
3	64.46	3	87.93
5	74.71	5	92.42
7	82.26	7	94.75
10	89.72	10	97.08
12	93.15	12	98.08
14	95.61	14	98.91
16	97.45	16	99.33
18	98.68	18	99.66
20	99.29	20	99.75
24	100	22	99.83
26	100	24	100
28	99.82	26	99.66
29	99.64	27	99.58
		25	99.75

MV=Mega Volt, mm=millimeter,
PDD= Percentage Depth Dose

The above-mentioned results were in accordance with our measured beam attenuation values at gantry angles of 0°-180°, in which the maximum attenuation was 5.95% at 130° gantry angle. It was found that attenuation increased with larger beams passing through the couch, which in turn, enhanced the surface doses.

The representative depths of acute and late skin radiation reactions for erythema and subcutaneous fibrosis are considered to range between 0.1 mm and 2 mm [16, 17]. In the current study, the beam entrance dose at 0.5 cm depth with 18 MV energy and 10×10 cm² field size increased from 65.9% to 87.95% of depth of maximum (dmax) dose. These results are in line with the findings of Spezi and Ferri [18], proposing that the percentage depth dose

Table 4: Comparing Build-up region with and without 550 TxT couch at 6 MV and 10×10 cm² field size

6 MV (10×10 cm²)			
Depth (mm)	PDD (without couch)	Depth (mm)	PDD (with couch
0	43.33	0	94.06
1	62.54	1	97.3
3	79.58	3	98.83
5	89.39	5	99.73
7	94.83	7	100
10	98.8	8	99.91
12	99.81	10	99.82
13	99.9		
14	100		
15	99.81		

MV=Mega Volt, mm=millimeter,
PDD= Percentage Depth Dose

Table 5: Comparing Build-up region with and without 550 TxT couch at 6 MV and 10×10 cm² field size

6 MV (20×20 cm²)			
Depth (mm)	PDD (without couch)	Depth (mm)	PDD (with couch
0	61.01	0	97
1	68.52	1	98.2
3	83.73	3	99.31
5	92.09	5	99.82
7	96.48	7	100
12	99.91	8	99.74
13	100	10	99.82
14	99.82		
15	99.73		

MV=Mega Volt, mm=millimeter,
PDD= Percentage Depth Dose

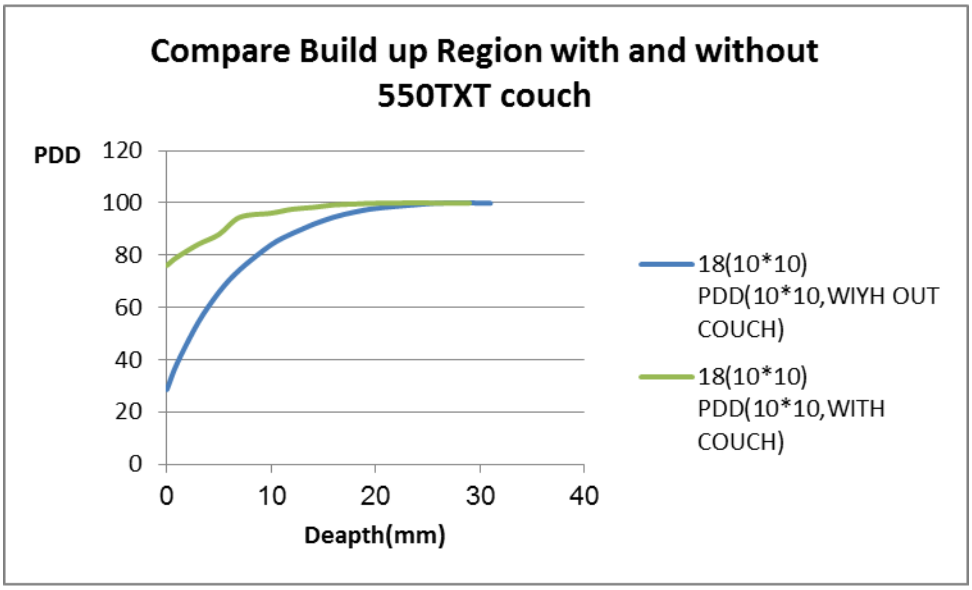

Figure 6: Comparing buildup region with and without 550 TxT couch at 18 MV and (10×10 cm^2) field size

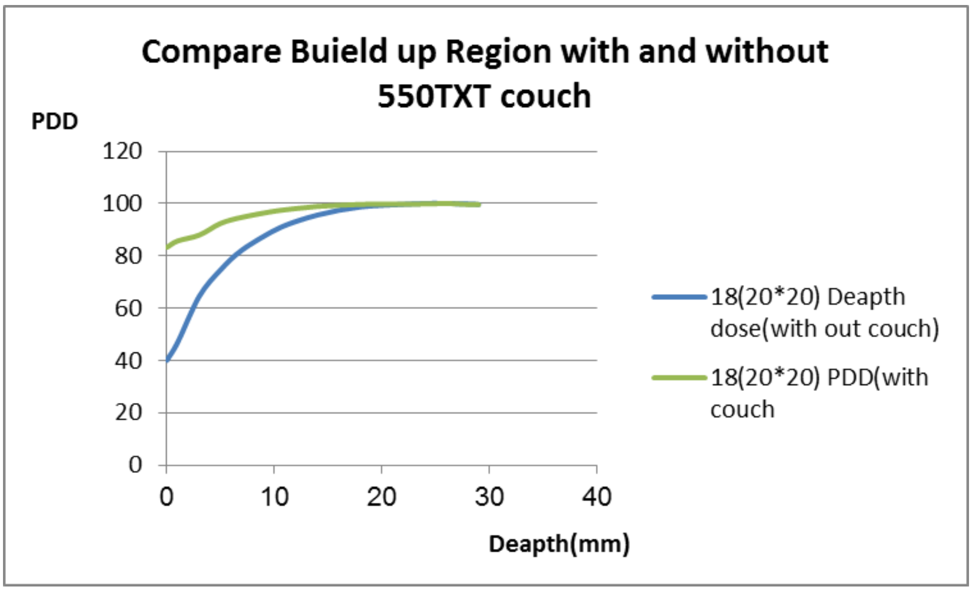

Figure 7: Comparing buildup region with and without 550TxT couch at 18 MV and (20×20 cm^2) field size

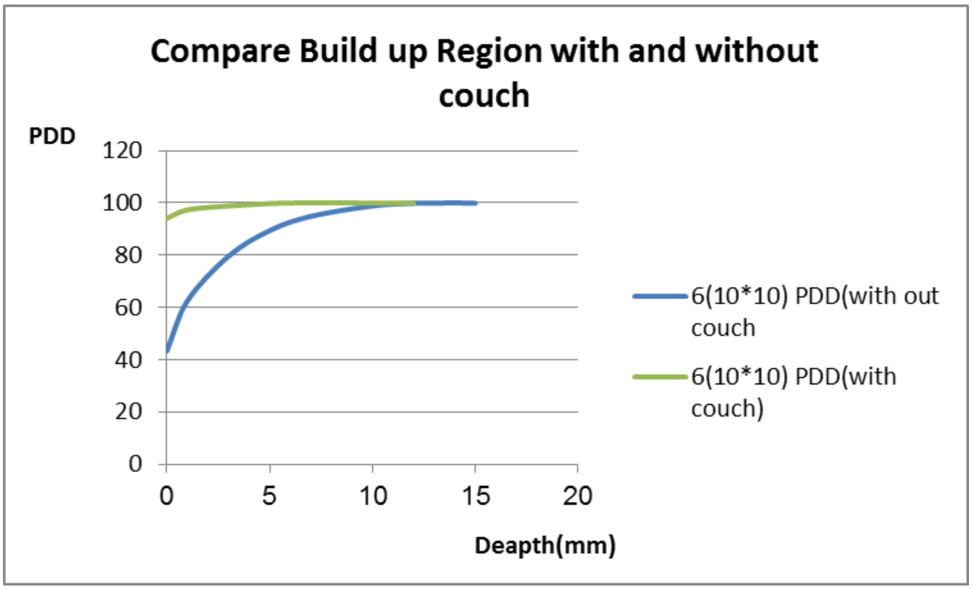

Figure 8: Comparing buildup region with and without 550TxT couch at 6 MV and ($10×10\ cm^2$) field size

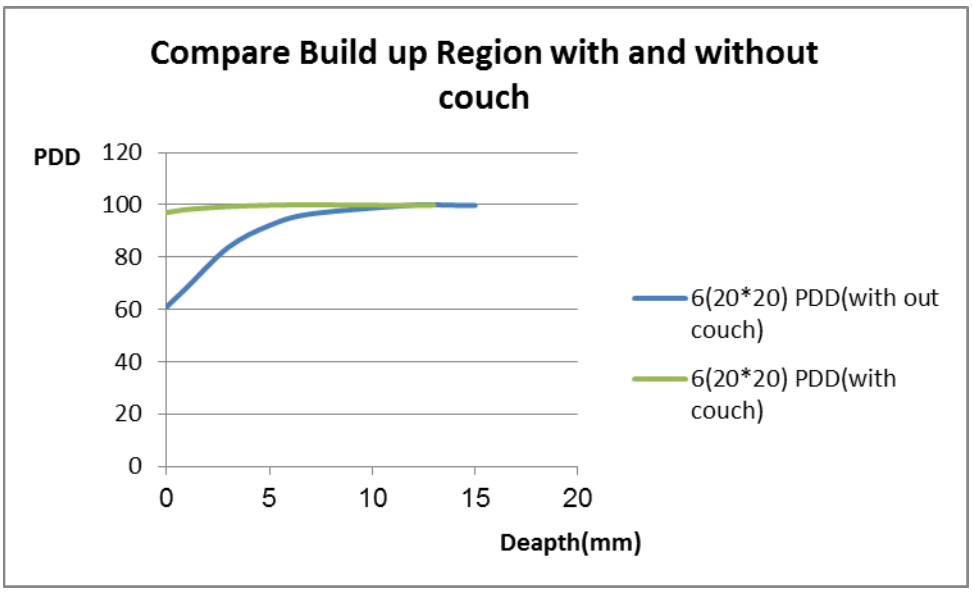

Figure 9: Comparing buildup region with and without 550 TxT couch on 6 MV and ($20×20\ cm^2$) field size

(PDD) at 0.5 cm depth increased from 82% to 97% at dmax dose. Since carbon fiber couch-top attenuated photon beam, the dmax dose also changed from 28 mm to 24 mm and from 26 mm to 24 mm with carbon fiber.

Couchtop attenuation at 10×10 cm^2 to 20×20 cm^2 field sizes, for 6 MV at 0.5 cm depth increased from 89.39% to 99.73% and from 92.09% to 99.82% at dmax dose; moreover, dmax dose changed from 14 mm to 7 mm and from 13 mm to 7 mm, respectively. Our results revealed that carbon fiber couch considerably enhanced skin dose with posterior beam. The skin-sparing effect, reduces erythema, moist desquamation and permanent hair loss [3]. Our results are in agreement with previously published studies [2, 3]. De Ost et al. showed that the probability of skin reactions is higher with the posterior beam than with the anterior one [10]. Furthermore, the range of increase in beam attenuation and surface dose were relatively larger for the smaller beam sizes.

Conclusion

In this study, the dosimetric properties of 550 TxT treatment couch were investigated. In summary, carbon fiber couch reduces the skin-sparing effect of megavoltage beams. Enhanced beam attenuation and patient skin dose should be taken into account in the process of treatment planning. The presented data can be used in treatment planning systems to lower surface doses and photon beam attenuation.

Acknowledgment

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Conflict of Interest

The authors declare no conflicts of interest.

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