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Original research article

Absorption ratio of treatment couch and effect on surface and build-up region doses

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ABSTRACT

Aim: In this study, at different fields, energies and gantry angles, treatment couch and rails dose absorption ratio and treatment couch effect on surface and build-up region doses were examined.

Background: It is assumed that radiation attenuation is minimal because the carbon fiber couches have low density and it is not generally accounted for during treatment planning. Consequently, it leads to a major dosimetric mistake.

Materials and methods: Solid water phantom was used for relative dose measurement. The measurements were done using a Farmer ion chamber with 0.6 cc volume and a parallel plane ion chamber starting from surface with 1 mm depth intervals at $10 \times 10\,\text{cm}^2$ field, SSD 100 cm. Measurements were taken for situations where the beams intersect the couch and couch rails.

Results: Dose absorption ratio of carbon fiber couch obtained at gantry angle of 180° was 1.52%, 0.69%, 0.33% and 0.25% at different field sizes for 6 MV. For 15 MV, this ratio was 0.95%, 0.27%, 0.20% and 0.05%. The absorption ratio is between 3.4% and 1.22% when the beams intersect with couch rails. The couch effect increased surface dose from 14% to 70% for 6 MV and from 11.34% to 53.03% for 15 MV.

Conclusions: The results showed that the carbon fiber couch increased surface dose during posterior irradiation. Therefore, the skin-sparing effect of the high energy beams was decreased. If the effect of couch is not considered, it may cause significant differences at dose which reaches the patient and may cause tissue problems such as erythema.

1. Background

High energy X beams are often used in cancer treatment. High energy X beams display a skin-sparing effect. Therefore, high dose locate at a depth than tissue region in skin.[13] The contaminated low X beams and electrons cause dose increase at the skin and build-up region.[9–13] Therefore, some tissue trouble may occur in patients treated with radiation therapy in early and late effect. The most radiosensitive layer of the epidermis contains the epithelial cells which are located at the depth of approximately 0.07 mm in the tissue.[10,19] It is important to measure accurately the absorbed dose at the surface and in the build-up region for high energy photon beams.[2,3,13]

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The carbon fiber couches are commonly used in radiation therapy. It is assumed that radiation attenuation is minimal because carbon fiber couches have low density and it is not generally accounted for during treatment planning. Consequently, it leads to a major dosimetric mistake.[14,15,20] Some researchers have reported that the carbon fiber table decreases the skin-sparing effect and causes dose attenuation. Furthermore, in this research, especially in stereotactic body radiation (SBRT), volumetric arc treatment (VMAT) and intensity modulated radiation therapy (IMRT), negative effect of the carbon fiber table is indicated because some beams intersect with carbon fiber table rails during treatment.

In these days, diodes, thermo luminescent dosimeter (TLD), radiochromic films, optically stimulated luminescent (OSL) detectors, parallel plan ion chambers, extrapolation chambers and metal oxide field effect transistor (MOSFET) are used to measure surface and build-up region doses.[11,12,13,18] Surface and build-up region doses are measured with extrapolation chambers most accurately.[1,9,18] Parallel plan ion chambers are a valid alternative to extrapolation chambers, but unlike extrapolation chambers, perturbation corrections are required under disequilibrium conditions.[18] In Task Group 176, published by the American Association of Physicists in Medicine (AAPM), the treatment couch attenuation and surface dose measurement are indicated.

2. Aim

In this study, at $3\times3\,cm^2$, $5\times5\,cm^2$, $10\times10\,cm^2$ and $15\times15\,cm^2$ fields, for 6 and 15 MV photons, at different gantry angles, treatment couch and rails dose absorption ratio and treatment couch effect on surface and build-up region doses were examined.

3. Materials and methods

Dose measurements were made using 6 and 15 MV high energy photons. The couch top used is CIVCO carbon fiber couch top with production number MTIL3015. $30\times30\,cm^2$ solid water phantom (PTW-RW3) was used for relative dose measurement. The dose absorption ratio of carbon fiber couch was done using a PTW Farmer ion chamber with 0.6 cc volume, at $3\times3\,cm^2$, $5\times5\,cm^2$, $10\times10\,cm^2$ and $15\times15\,cm^2$ fields, 5.3 cm depth, source–surface distance (SSD) of 100 cm for 6 and 15 MV photon beams. The ion chamber was placed in the center of phantom. The phantom was placed in the center of couch at lateral axis in order to measure all irradiations at same SSD. After the reference measurements were obtained at gantry angle 0°–55°–305°, these values were compared with opposed gantry angles (180°–235°–125°). The reason for use of gantry angle 235°–125° is that the beam center intersects with the couch rails.

The measurements of surface and build-up region doses were taken with a parallel plane ion chamber starting from the surface with 1 mm depth intervals at $10\times10\,cm^2$ field, SSD 100 cm for 6 and 15 MV photons. Entry window of the parallel plane ion chamber was directed toward the source.[16] Results of the measurements were obtained for gantry angle 0°–180°. Percent depth dose (PDD) curves were created with and without carbon fiber couch. PDD was defined as the ratio of absorbed dose at the depth to maximum absorbed dose along the beam axis. The results of the measurements were read with PTW-UNIDOS E electrometer.

Extrapolation ion chamber provides the most correct measurement for the surface and build-up dose of MV beams. Most perturbations introduced by ion chambers are eliminated with the use of an extrapolation chamber. Perturbation corrections are required under disequilibrium conditions.[18] In general, parallel plane ion chambers display a polarity effect and this can be significant in regions of electronic disequilibrium such as the build-up region. Polarity effect of the ion chamber was considered and this effect was corrected with an average of positive and negative bias voltage measurements.

$$Q_{avg} = (Q_+ + Q_-)/2$$

Q_+ and Q_- are measurement values at positive and negative bias voltage. Q_{avg} is an average of relative measurements.

Parallel plan ion chambers are a valid alternative to extrapolation chambers but these ion chambers give over response when surface and build-up dose are measured.[24] The over response occurs by secondary electrons which scatter from the wall of the chamber (Fig. 1).

Gerbi's over response correction factor can be used for parallel plane chambers.[1,4,21]

In this study, Gerbi's method was applied for correction of PDD curves which were obtained in the build-up region.

$F(d, E) = P(d, E) - \xi(0, E)Ie^{-\alpha(d/d_{max})}$[4]

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

E: Energy

$F(d, E)$: Corrected PDD

(d, E): The dose at relative depth

IR: ionization ratio at depths of 20 cm and 10 cm, which is measured at a constant SSD and $10\times10\,cm^2$ field size (0.669 and 0.763 for 6 and 15 MV)

C: Sidewall collector distance (0.35 mm for PTW-Markus 23343)

I: plate separation (2 mm for PTW-Markus 23343[23])

α: 5.5 (constant) d_{max}: maximum dose depth

d: Depth of the chamber front window ($d = 0$ for surface)

4. Results

The ratio of the carbon fiber couch dose attenuation was measured at $3\times3\,cm^2$, $5\times5\,cm^2$, $10\times10\,cm^2$ and $15\times15\,cm^2$ fields for 6–15 MV photons. In Fig. 2, dose absorption ratio of the carbon fiber couch at different gantry angles was displayed for 6–15 MV photon beams.

Dose absorption ratio of carbon fiber couch obtained at gantry angle of 180° was 1.52%, 0.69%, 0.33% and 0.25% at $3\times3\,cm^2$, $5\times5\,cm^2$, $10\times10\,cm^2$ and $15\times15\,cm^2$ field sizes for 6 MV. For 15 MV, this ratio was 0.95%, 0.27%, 0.20% and 0.05% (Fig. 3). It was concluded that the dose absorption ratio decreases when field size and energy increases.[17] For gantry angle of 180°, maximum dose absorption ratio was observed at $3\times3\,cm^2$ field and 6 MV energy.

For gantry angle of 125° and 235° at which the beams intersect with couch rails, dose absorption ratio is 3.40%, 2.69%, 2.32%, 1.97% at gantry angle 125° and $3\times3\,cm^2$, $5\times5\,cm^2$,

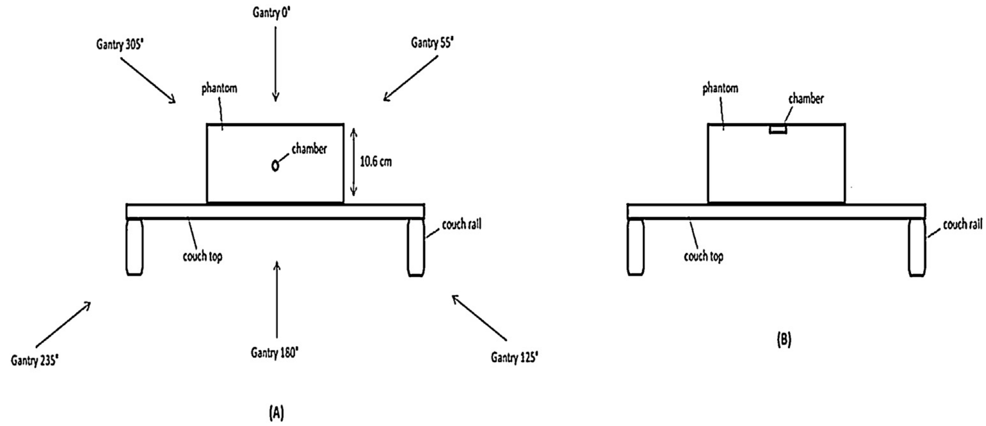

Fig. 1 – (A) Measurement layout for couch attenuation. (B) Measurement layout for surface and build-up region doses.

(A)

	Absorption in %		
	0° to 180°	125° to 305°	235° to 55°
Field			
3x3	1.52	3.40	3.37
5x5	0,69	2.69	2.66
10x10	0,33	2,32	2.28
15x15	0,25	1.97	1.97

(B)

	Absorption in %		
	0° to 180°	125° to 305°	235° to 55°
Field			
3x3	0,95	2.42	2.41
5x5	0,27	1 68	1.67
10x10	0,20	1.26	1.24
15x15	0.05	1.22	1.22

Fig. 2 – (A) Ratio of dose attenuation at different field and gantry angles for 6 MV. (B) Ratio of dose attenuation at different field and gantry angles for 15 MV.

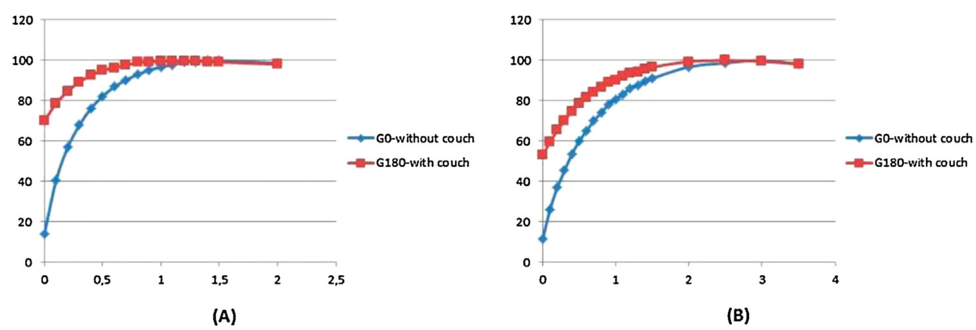

Fig. 3 – (A) For 6 MV PDD curves at 10 × 10 cm² field size and gantry angle 0°–180°. (B) For 15 MV PDD curves at 10 × 10 cm² field size and gantry angle 0°–180°.

10 × 10 cm² and 15 × 15 cm² field sizes for 6 MV. For 6 MV at gantry angle of 235°, this ratio is 3.37%, 2.66%, 2.28%, and 1.97% at 3 × 3 cm², 5 × 5 cm², 10 × 10 cm² and 15 × 15 cm² field sizes.

For 15 MV at gantry angle of 125°, the dose absorption ratio is 2.42%, 1.68%, 1.26%, and 1.22% at 3 × 3 cm², 5 × 5 cm², 10 × 10 cm² and 15 × 15 cm² field sizes. For 15 MV at gantry angle 235°, the dose absorption ratio is 2.41%, 1.67%, 1.24%, and 1.22% at 3 × 3 cm², 5 × 5 cm², 10 × 10 cm² and 15 × 15 cm² field sizes.

The absorption ratio is between 3.4% and 1.22% when the beams intersect with couch rails. This ratio is much higher in small fields.

PDD was obtained with 1 mm intervals for surface and build-up region doses at 10 × 10 cm² field size and gantry angle of 0°–180° for 6–15 MV photon energy.

The Gerbi's correction method was applied to all results. For 6 MV, when the maximum dose (D_{max}) is reference dose, the surface dose is 14% for gantry angle 0° and %70 for gantry angle 180°. Besides the surface dose at 5 mm and 10 mm is 82.2–96.6% for gantry angle 0° and 94.9%–99.4% for gantry angle 180°. The couch effect increased surface dose from 14% to 70% for 6 MV.

For 15 MV, when D_{max} is reference dose, the surface dose is 11.34% for gantry angle 0° and 53.03% for gantry angle 180°. Besides the surface dose at 5 mm and 10 mm is %59.9–80.6% for gantry angle 0° and 78.4%–90.3% for gantry angle 180°. The couch effect increased surface dose from 11.34% to 53.03% for 15 MV.

5. Conclusions

As expected, dose attenuation effect of carbon fiber couch was seen when beams intersected with carbon fiber couch. The absorption ratio of the couch changes depending on field size and energy. The values which were obtained for couch absorption ratio at different field are between 1.52% and 0.25% for 6 MV and gantry angle 180°. These results for 15 MV are between %0.95 and 0.05%. Meara et al.[8] found absorption ratio between 0.3% ± 3 and 0.8% ± 3 at 8 × 8 cm^2 field size for 5, 6, 8 MV when they examined dose transmission of different carbon fiber couch. In additional, De Ost et al.[5] found between 0% and 1% at 10 × 10 cm^2 field for 6 MV, near to 0% for 23 MV. The datas obtained from us are compatible with these results. The results obtained at irradiations that intersect with couch rails are greater than the results which are no intersection. At gantry angle 125°–235° and in different fields, the results are between 3.4%–1.97% for 6 MV and 2.42%–1.22% for 15 MV. As average, the result obtained at 10 × 10 cm^2 field is 2.3% for 6 MV and 1.25% for 15 MV. When Seppala et al.[7] examined different carbon fiber couch, they found attenuation ratio as 7.7%–1% for 6 MV and 5.1%–0.6% for 15 MV at 10 × 10 cm^2 field and gantry angle 125°. In additional, Seppala et al.[7] found attenuation ratio as 5%–1.3% for 6 MV and 3.3%–0.9% for 15 MV for measurements between gantry angles 100°–180°. Our data are compatible with these values.

When the effect of carbon fiber couch on the surface and build-up region dose is examined, it is observed that the carbon fiber couch increases the dose on the surface and build-up region. In addition, the maximum dose depth shifts toward the surface for all energies.[22] The carbon fiber couch behaves like a bolus. When the difference between PDDs at gantry angle of 100° and 180° is examined, there is a difference in the build-up region. This difference disappears under the build-up region and remains the same for both gantry angles. In our study, for 6 MV and at gantry angle of 0°, the surface dose was measured with a parallel plane ion chamber and we obtained 14% at SSD 100 cm. In the same conditions, Yadav et al.[2] found 14.8%, Bilge et al.[1] found 15% and Akbas et al.[9] found 16.6%. When the couch top was used, the results almost doubled at 1 mm depth. The dose at 5 mm depth is 82% without couch top and 95% with couch top for 6 MV. Meydanci et al.[13] measured that the dose increased from 82% to 98%. In our study, at 5 mm depth, when the couch top used, the maximum dose depth shifted from 1.5 mm to 1 mm for 6 MV and from 2.8 mm to 2.3 mm for 15 MV. Spezi et al.[6] found that the maximum dose depth decrease was around 4 mm when the carbon fiber couch was used. These results showed that the carbon fiber couch increased surface dose during posterior irradiation. Therefore, the skin-sparing effect of the high energy beams was decreased. This may lead to erythema and hair loss.

We examined carbon fiber couch permeability and the effect on surface and build-up region doses. The results of the study showed that the dose effect of carbon fiber couch caused dose to decrease during posterior and angled posterior irradiation. This reduction is the highest when the beams intersect with couch rails. The absorption ratio of carbon fiber couch increases as energy and field size decrease. Today, in the most commonly used small field treatment modalities such as SBRT, VMAT and IMRT, the effect of carbon fiber couch may cause significant differences at dose which reaches the patient. Therefore, the effect of carbon fiber couch should be considered during treatment planning. The surface dose increases and skin-sparing effect decreases when the carbon fiber couch is used. The maximum dose depth shifts to the surface because the couch top shows bolus effect. This assumption shows that the carbon fiber couch permeability is significant. If the effect of carbon fiber couch is not considered, the dose in the center may be significantly reduced when the beams intersect with couch rails. This reduction may make significant differences in treatment which uses very posterior beams. The effect of carbon fiber couch at dose should be considered and necessary corrections should be made.

Conflict of interest

None declared.

Financial disclosure

None declared.

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