Original Article

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An Empirical Approach to Dosimetric Effect of Carbon Fiber Couch for Flattening Filter Free Beam of Elekta LINAC

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Generally, it is recommended that the dosimetric effect of carbon fiber couch should be considered especially for an intensity-modulated therapy with a large portion of monitor units from posterior angles. Even a flattening filter free (FFF) beam has been used for stereotactic body radiation therapy (SBRT), the effect of carbon fiber couch for FFF beam is not well known. This work is an effort to evaluate the dosimetric effect of carbon fiber couch for flattened and FFF beam of Elekta linac empirically. The absorbed doses were measured with Farmer type chamber and water-equivalent phantoms with and without couch. And differences of the absorbed doses between with and without couch defined as “couch effect”. By comparing calculated dose in treatment planning system (TPS) with measured dose, the optimal density of couch was evaluated. Finally, differences on patient’s skin dose and target dose by couch were evaluated in TPS. As a result, the couch effect for 6 and 10 MV flattened beam were −2.71% and −2.32%, respectively. These values were agreed with provided data by vendor within 0.5%. The couch effect for 6 and 10 MV FFF beam were −3.75% and −2.80%, respectively. The patient’s skin dose was increased as 18.6% and target dose was decreased as 0.87%, respectively. It was realized that the couch effect of FFF beam was more severe than that of flattened beam. Patient’s skin dose and target dose were changed by the couch effect.

Key Words: Flattening filter free (FFF), Elekta, Carbon fiber couch, Dosimetric effect, Skin dose, Target dose

Introduction

Recently, rotational and intensity modulated techniques are becoming the most common treatment techniques in radiotherapy. Increasing trends of using these complex techniques will continue, providing better conformity in the target than 3-dimensional conformal radiation therapy. The ratio of beams passing through a couch will also increase, therefore the impact of couch attenuation for radiotherapy is being an important parameter which has to be considered in treatment planning system (TPS).

Several researchers have been studying the couch effect.[1-10] Monique et al.[1] studied the impact of Varian Exact Couch (Varian Medical Systems, Palo Alto, CA) on dose calculation and they have observed that couch intersection caused up to a 3% reduction in planning target volume (PTV) coverage. Alessandro et al.[2] modeled carbon fiber couch (Varian Medical Systems, Palo Alto, CA) in treatment planning system (TPS), RayStation® (Raysearch Laboratories, Stockholm, Sweden). They reported an absolute deviation between measured and calculated dose was within 1.0%. Ivaylo et al.[3] observed that skin doses in excess of 68% and 80% of the prescription doses for mixed and 6 MV energy plans, respectively, due to the bolus effects of BrainLab’s carbon fiber couch.

Even a flattening filter free (FFF) beam has been used for stereotactic body radiation therapy (SBRT), to the best of our

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knowledge, no research on this topic has yet been carried out concerning FFF beam and Elekta carbon fiber couch. In addition, AAPM TG-176 report[11] recommends that the verification should be performed to apply carbon fiber couch to TPS even if the data is provided by vendor. This work is an effort to evaluate the dosimetric effect of carbon fiber couch for FFF beam of Elekta linac empirically.

Materials and Methods

Elekta iBEAM® evo couchtop EP was used in this study. We used an empty metal frame below to create a setup without a couch (Fig. 1). In this study, the difference in dose measured under the same conditions except couch was defined as couch effect. The couch effect was quantitatively compared by calculating the percent dose difference as shown in equation 1. The couch effects were measured for 6 and 10 MV FFF beams and flattened beams in Versa HD (Elekta, Stockholm, Sweden). The solid water phantoms, RW3 Slab Phantom (Sun Nuclear Corporation, FL, USA), were stacked, and farmer type chamber was placed at a depth of 10 cm at a SAD of 100 cm. And the absorbed dose was measured every 5 degrees while rotating from a gantry angle of 130 to 180 degrees to a clockwise direction with a reference field size of 10×10 cm^2.

$$Percent\ dose\ difference = \frac{(D_{couch} - D_{empty})}{D_{empty}} \times 100 \qquad (1)$$

We acquire CT dicoms of farmer chamber and RW3 phantom and registered in RayStation®. Thickness of the couch in RayStation® was set to 5.0 cm according to the dimension data provided by the vendor. To evaluate the couch effect in TPS, the point dose differences at the position of farmer chamber were evaluated between with and without couch geometry (Fig. 2). We determined the density of couch that best matches the couch effect obtained from the experiment.

Finally, the difference in patient dose due to the couch effect was evaluated by comparing the skin dose and the target dose in 6 MV VMAT treated patient.

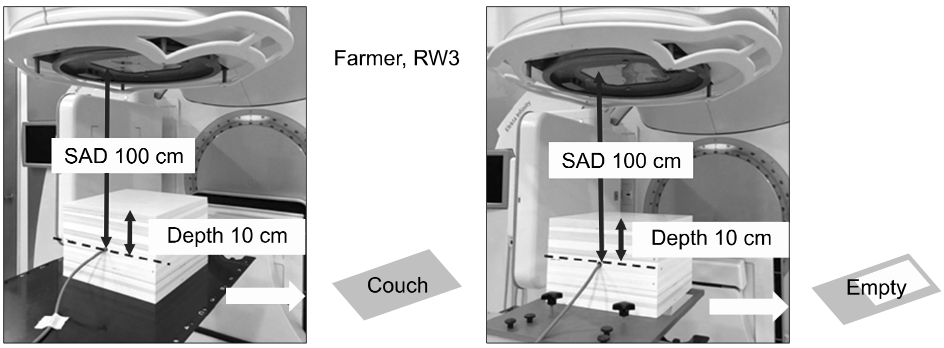

Fig. 1. The experimental setup. An empty metal frame was used to create a setup without a couch. The solid water phantoms (RW3) were stacked, and farmer type chamber was placed at a depth of 10 cm at a SAD of 100 cm.

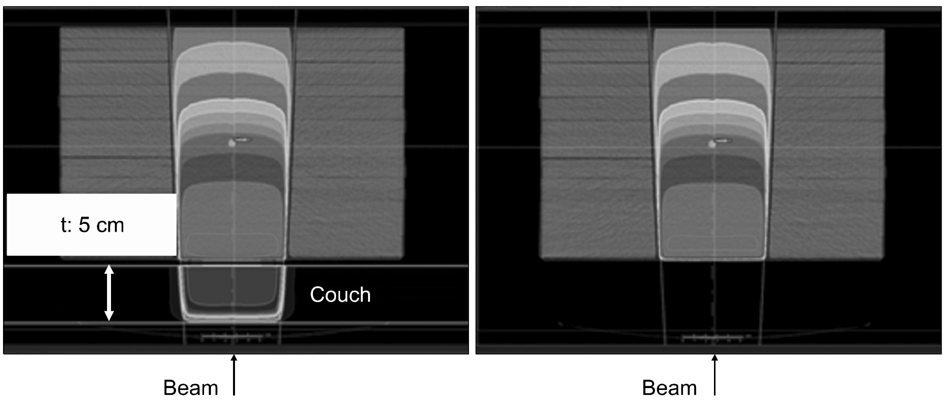

Fig. 2. The point dose differences at the position of farmer chamber were evaluated between with and without couch geometry.

Results

Table 1 shows the percent dose differences for each energy. For the flattened beams, the percent dose differences were −2.71 and −2.32% for 6 and 10 MV, respectively. We realized that the couch effect is more severe for low energy beam than high energy beam. For the FFF beams, the percent dose differences were −3.75 and −2.80% for 6 and 10 MV, respectively. It was founded that the couch effect is more severe for FFF beam than flattened beam. The couch effect was well matched with the data provided by the vendor within 0.5%, confirming the reliability of our experiment. Fig. 3 shows the angular distribution of percent dose differences for the 6 MV FFF beam with the largest couch effect. The couch effect was more severe in the 130 degrees than in the 180 degrees beam. It is because the beam travels in the couch longer in 130 degrees than 180 degrees.

When the couch effect was calculated under the same conditions as the experiment, we tried to find a density that makes it well matches within 0.5% of the experiment. The density optimized for each energy was slightly different with each other. Because all energies are used to treatment, we set the couch density to 0.16 g/cm^3, which is the average value of these values.

The couch effect was evaluated for the patient's skin dose and target dose. As shown in isodose curves (Fig. 4), skin dose increased by about 18.6% and target dose decreased about −0.87% due to couch effect at same position.

Table 1. The percent dose differences for each energy (unit: %).

Field sizes (cm×cm)	6 MV (FF)	10 MV (FF)	6 MV (FFF)	10 MV (FFF)
10×10	−2.71	−2.32	−3.75	−2.80
Vendor (10×10)	−2.40	−1.90	NA	NA

Discussion

The results show that the lower energy has the severe couch effect. The reason is that the lower energy beam has the more beam hardening, therefore the bolus effect is emphasized. Also, it was realized that the couch effect of the FFF beam was more severe than that of the flattened beam. For flattened beam, it is considered that the low energy beam is absorbed by passing through the flattening filter and the bolus effect is relatively low.

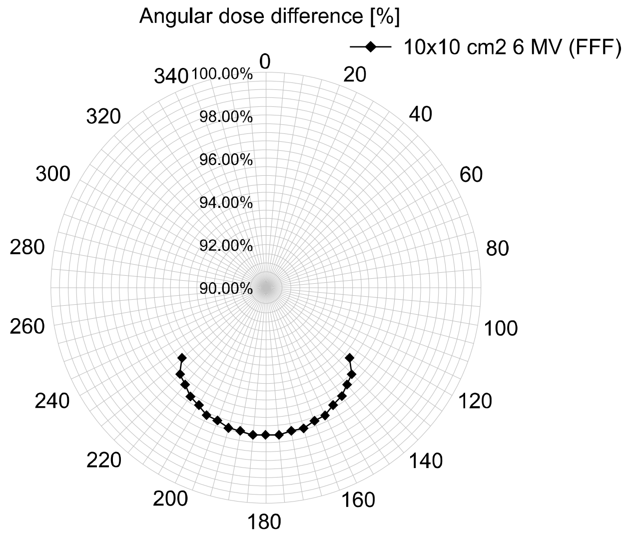

Fig. 3. The angular distribution of percent dose differences for the 6 MV FFF beam.

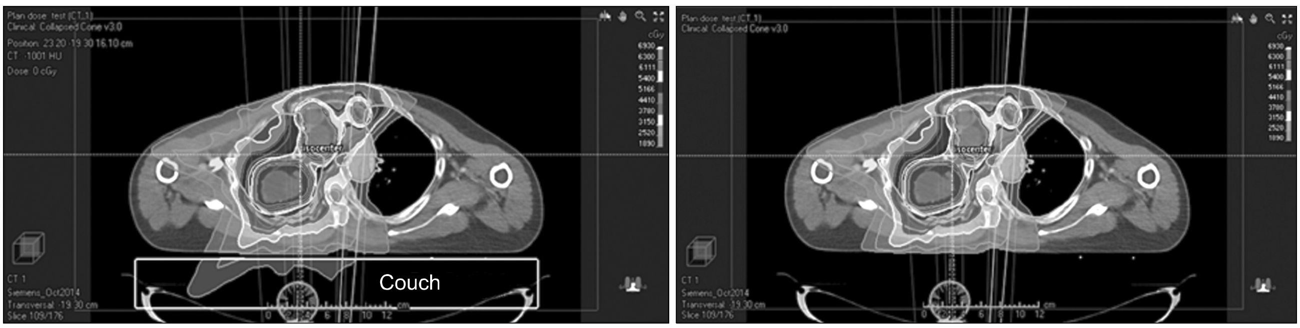

Fig. 4. The couch effect was evaluated for the patient's skin dose and target dose.

We also extend the result of angular percent dose difference for the overall treatment plan. If 360 degrees full static arc treatment is applied so that equivalent MUs are delivered for all angles without considering couch in treatment planning, the actual delivery dose may be lower by 1.0% than the treatment plan. The dose difference could be more severe with the higher portion of MUs from the posterior beam. Therefore, in order to keep the dose difference by the couch effect below 1.0%, it is suggested to set the MUs transmitting 130 to 180 degrees and 310 to 360 degrees beams to be less than 30% of the total MUs.

This study was performed only for a 10×10 cm^2 field size. The portion of small segments in IMRT or VMAT treatment is increasing with use of IGRT. Especially, ablative treatment for small target using FFF beams is increasing. Therefore, the couch effect on the small field is also worth studying. However, to evaluate the couch effect on the small field, a smaller sensitive volume chamber than the Farmer type chamber used in this study should be used. Smaller sensitive volumes of ion chamber can result in distorted results even with relatively small positioning uncertainty. Therefore, a method to minimize the positioning deviation should be sought for evaluating the couch effect on small field.

In order to consider the couch in the planning of the actual patient's treatment plan, it is important that the position between the couch and the patient is always kept constant. This is because if the patient lies in a different location on couch each treatment, the patient dose may be given differently from planned dose with the couch effect on TPS. The AAPM TG-176 also recommends the use of an indexed system to solve these positioning uncertainty problems. We will also be studying on the development of indexed systems before we consider the couch effect on the treatment plan.

Conclusion

We evaluated the dosimetric effects of the Elekta carbon fiber couch for flattened and FFF beams. It was realized that the couch effect of FFF beam was more severe than that of flattened beam. Before registering couch in the TPS, the couch density was optimized to show good dose values within 0.5% of the experimental results. The application of couch to the dose calculation of patients showed that the skin dose was increased and the target dose was decreased.

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