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Dose attenuation in intensity-modulated radiotherapy and volumetric modulated arc therapy caused by different treatment couches

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Abstract

Posterior oblique beams is used widely in intensity-modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT). Dose attenuation by the treatment couch is not neglectful when fields below the treatment couch.This study aimed to analyze the dose attenuation caused by four kinds of commonly used commercial treatment couches (Elekta iBEAM evo Couch, Varian Exact Couch (Standard Couch), Varian Exact IGRT Couch, and BrainLAB imaging Couch) in IMRT and VMAT. Six patients with prostate cancer were

planned with both 6 MV 5-field , 7-field , 9-field IMRT plan and 2-arc (152º-212º and 210º-150º) VMAT plan in the treatment planning system (TPS). We compared the dose distribution difference with and without treatment couches in the TPS. The mean dose, dose covering 95% of the target volume, and the isocenter dose of the planning target volume were evaluated. The dose attenuation was 1.46%-3.13% with Elekta iBEAM evo Couch, 0.72%-1.63% with Varian Exact Couch (Standard Couch), 0.86%-2.02% with Varian Exact IGRT Couch, and 1.51%-3.15% with BrainLAB imaging Couch. In the clinical evaluation, the dose attenuation was 1.24%- 3.15% in 5F- IMRT, 0.73%- 1.73% in 7F- IMRT, 1.39%-2.83% in 9F- IMRT, and 0.72%-1.78% in VMAT. In addition, we found that the relative position between the patient and treatment couch was changed daily according to the record in the Elekta Mosaiq system. The shift of the treatment couches relative to the patient's position ranged from -2.00 cm to +2.00 cm. Simulation of treatment couch shift in the TPS showed that a treatment couch shift by 2 cm to the right or the left caused a maximum dose change of 0.65% and an average dose change of less than 0.30%. The dose attenuation caused by the treatment couch is obvious in IMRT and VMAT, suggesting the necessity of incorporating the accurate couch model in the TPS to minimize dose difference between the computed dose in TPS and the delivered dose to patient in actual treatment. The average dose attenuation is less in 7F-IMRT and VMAT than in 5F-IMRT and 9F-IMRT among four treatment couches. Varian Exact Couch (Standard Couch) and Varian Exact IGRT Couch cause less average dose attenuation than Elekta iBEAM evo Couch and BrainLAB imaging Couch. The position of patients relative to the treatment couch, which may vary in daily set-up, does not cause significant impact on the target dose in the treatment.

Keywords: Prostatic Cancer, Treatment Couch, Dosimetry, Intensity-modulated Radiotherapy(IMRT), Volumetric Modulated Arc Therapy(VMAT)

Introduction

Nowadays with intensity-modulated radiotherapy (IMRT),volumetric modulated arc therapy (VMAT)and other radiotherapy technologies are more and more widely used, the requirements for precision of radiotherapy positioning and dose calculation are getting higher and higher. During the course of treatment， fields below the treatment couch are often used in IMRT and VMAT. The AAPM Task Group 176 [1] conducted a literature review of 53 papers on the dosimetric effects of external devices. It found the common range of dose

attenuation through carbon fibre treatment couch to be between 2 and 6%. Dose attenuation due to treatment couch is a major source of error if left unaccounted for in the treatment planning process. It is indispensable to take the dose attenuation caused by treatment couch fully into account [2-4].

In addition, the relative position between the patient and treatment couch was changed daily according to the record in the Elekta Mosaiq system. As result, the dose distributions may be varied in the course of treatment. However, it has not been studied in clinical research.

The focus of this paper is to study and analyze the effect of dose attenuation of treatment couch and dose effect caused by relative position change between treatment couch and patient.

Materials and methods

Cases selection

Six prostate patients admitted to MD Anderson cancer center were randomly selected. Age 35 to 65, median age was 48.

CT simulation

Each patient was scanned by Philips Brilliance Big Bore CT simulator. Supine position was adopted. The scanning range was from the lower margin of lumbar 4 vertebral to 3cm below the Ischia nodule, and the scanning thickness was 3mm.

Target and organs at risk（OAR）volume delineation

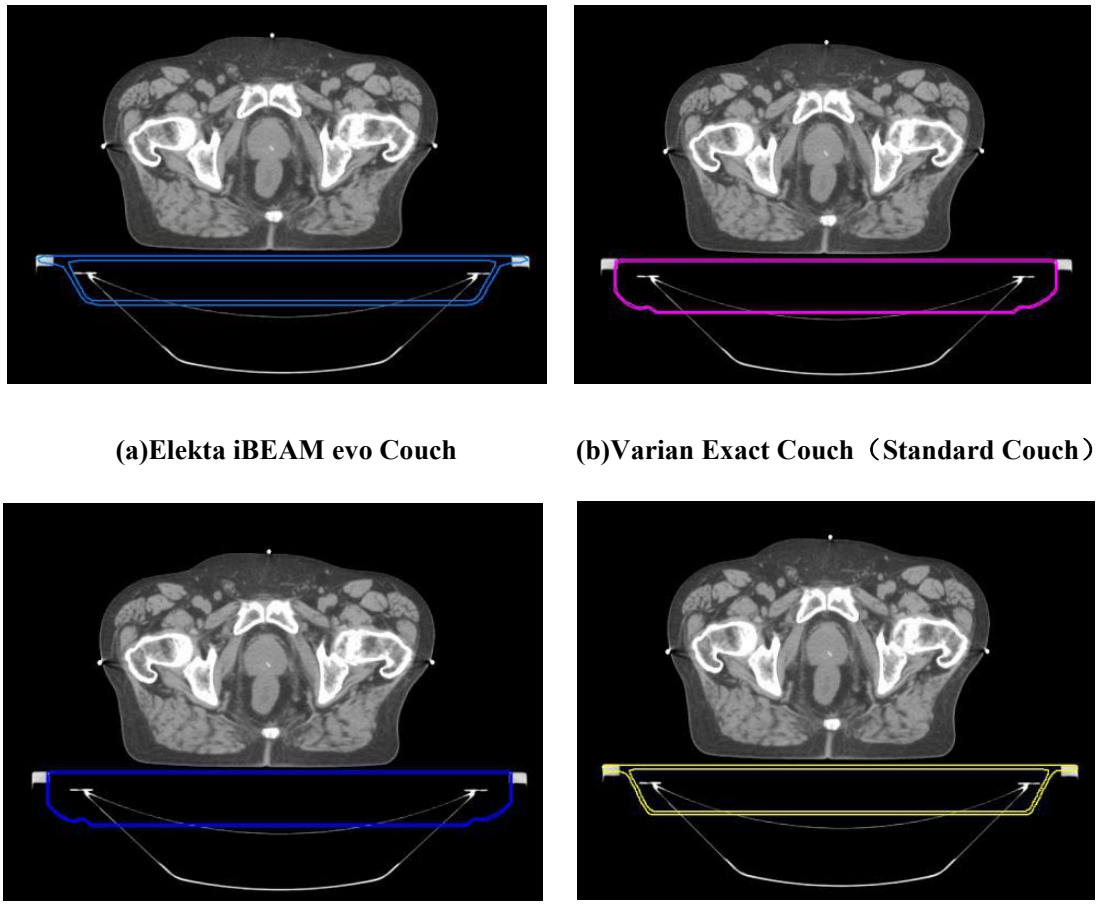
According to ICRU 62 report [5], clinicians delineated clinical target volume(CTV)and planning target volume(PTV) on CT image in combination with pathological and imaging data of patients. OARs include rectum, bladder, femoral head, small intestine, and colon.

Treatment planning

Each patient was planned with both 6 MV 5-field , 7-field , 9-field IMRT plan and 2-arc (152º-212º and 210º-150º) VMAT plan by medical physicists with Pinnacle planning system (Version: 9.80) . The beam angle distribution of the IMRT plan was uniform in the range of 0°-360°. It is widely used in clinic.

Dose attenuation calculation caused by treatment couch

All plans were optimized and calculated with and without treatment couches. When considering the influence of treatment couch， four kinds of commonly used commercial treatment couches models of Elekta iBEAM evo Couch, Varian Exact Couch (Standard Couch), Varian Exact IGRT Couch, and BrainLAB imaging Couch were imported into the treatment planning system (TPS).The model of treatment couch is shown in **Figure 1.**



(a)Elekta iBEAM evo Couch **(b)Varian Exact Couch（Standard Couch）**

(c)Varian Exact IGRT Couch **(d)BrainLAB imaging Couch**

Figure1. Four kinds of commonly used commercial treatment couches models

Dose effect of relative position changes between patient and treatment couch during radiotherapy

The coordinates of the treatment couch were recorded daily for each patient in the Elekta Mosaiq system . According to these data , the dose effect of relative position changes between patient and treatment couch was simulated by changing the position of treatment couches in TPS.

Evaluation parameters

The mean dose (D_{mean}), the dose of 95% of PTV(D_{95}) , and the isocenter dose (D_{iso}) were used to evaluate the dose effect.

Statistics

All data were statistically analyzed and processed by the Excel 2007 software.

Results

Dose attenuation caused by the treatment couch

The dose attenuation caused by the treatment couch is obvious in IMRT and VMAT, and the average dose attenuation ranges from -0.72% to -3.15%.The average dose attenuation of 7F-IMRT and VMAT is obvious less than in 5F- IMRT and 9F- IMRT. Varian Exact Couch (Standard Couch) and Varian Exact IGRT Couch cause less average dose attenuation than Elekta iBEAM evo Couch and BrainLAB imaging Couch. Therefore，it is very necessary to incorporate the treatment couch model in the TPS to minimize dose difference between the computed dose in TPS and the delivered dose to patient in actual treatment. Specific statistics are shown in **Table 1.**

Table 1. Average dose attenuation in the target area in IMRT and VMAT with 4 different treatment couches (%)

Treatment Couch	5F-IMRT			7F-IMRT			9F-IMRT			VMAT		
	D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}
Elekta iBEAM evo Couch	-2.73	-2.54	-3.13	-1.53	-1.46	-1.73	-2.82	-2.77	2.83	-1.65	-1.52	-1.75
Varian Exact Couch（Standard Couch）	-1.36	-1.24	-1.63	-0.77	-0.73	-0.82	-1.43	-1.39	-1.42	-0.84	-0.72	-0.89
Varian Exact IGRT Couch	-1.71	-1.56	-2.02	-0.97	-0.91	-1.05	-1.60	-1.55	-1.61	-0.99	-0.86	-1.06
BrainLAB imaging Couch	-2.71	-2.51	-3.15	-1.51	-1.44	-1.72	-2.75	-2.72	-2.75	-1.67	-1.53	-1.78

The dosimetric effect of relative position changes between the treatment couch and patient

The daily records of Elekta Mosaiq system shown that coordinates of the treatment couch X, Y and Z (patient's left and right, head and foot, front and back) changed every treatment，which indicating there is a shift of the treatment couch relative to the patient's set-up position. Take x-coordinate for an example, the daily records shown the shift of the treatment couch ranged from -2.00 cm to +2.00 cm, statistical data are shown in **Figure 2.** Simulation of treatment couch shift in the TPS showed that a treatment couch shift by 2 cm to the right or the left caused a maximum dose change of 0.65% and an average dose change of less than 0.30%，which does not cause significant impact on the target volume dose in the treatment. The specific data are shown in **Table 2.**

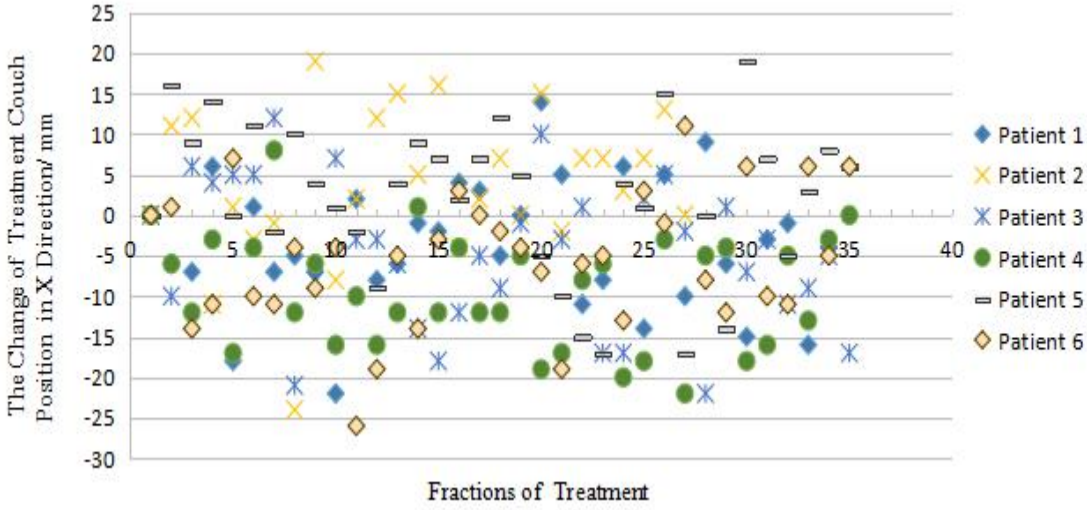


Figure 2. Change of position of treatment couch in X direction.

Table 2. Average change of the target dose caused by changes of the patients set-up position relative to treatment couch（X direction）(%)

Treatment Couch		5F-IMRT			7F-IMRT			9F-IMRT			VMAT		
		D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}	D_{mean}	D_{95}	D_{iso}
Elekta iBEAM evo Couch	Shift by 2 cm to the left	-0.07	-0.06	-0.11	-0.04	-0.04	-0.04	0.02	-0.02	-0.03	-0.06	-0.06	-0.07
	Shift by 2 cm to the right	-0.08	-0.07	-0.11	-0.04	-0.04	-0.04	0.01	0.00	-0.05	-0.04	-0.03	-0.06

Varian Exact Couch（Standard Couch）	Shift by 2 cm to the left	-0.13	-0.12	-0.06	-0.07	-0.06	-0.10	-0.08	-0.09	-0.13	-0.07	-0.08	-0.07
	Shift by 2 cm to the right	-0.18	-0.17	-0.13	-0.10	-0.08	-0.13	-0.08	-0.08	-0.14	-0.09	-0.09	-0.10
Varian Exact IGRT Couch	Shift by 2 cm to the left	0.11	0.10	0.20	0.07	0.07	0.06	0.02	0.00	-0.02	0.01	0.00	0.02
	Shift by 2 cm to the right	0.11	0.10	0.16	0.07	0.06	0.06	0.04	0.03	-0.02	0.03	0.02	0.03
BrainLAB imaging Couch	Shift by 2 cm to the left	0.06	0.05	0.05	0.03	0.03	0.03	0.10	0.09	0.08	0.02	0.02	0.03
	Shift by 2 cm to the right	0.01	0.01	-0.02	0.00	0.00	0.00	0.06	0.05	0.05	0.01	0.01	0.02

Discussion

In clinical treatment, multiple fields and arc fields were widely applied to IMRT in consideration of reaching the goal of higher prescribed dose, good conformality index for target，and sparing the normal tissue as much as possible. Consequently, the fields below the treatment couch are more and more applied in treatment, which could cause obvious dose attenuation[10-12] .

Li et al. [6] ‘s studies showed the maximum dose attenuation of the two types couches from Varian company was 2.6%（Varian Exact Standard Couch）and 2.1%（Varian Exact IGRT Couch）respectively in the 6MV IMRT and VMAT. Pulliam et al. [7] used Tumor Control Probability (TCP) [8] to evaluate the effect of dose attenuation caused by treatment couch. It shown the maximum decrease of TCP was 10.5%, and the average decrease was 6.3%.

Mihaylov et al.[9] analyzed the dose attenuation by incorporating the BrainLAB imaging Couch model in TPS (Pinnacle Version 8.0). It was conducted that treatment couch would increase the surface dose according to the percent depth dose(PDD) curves, and the

maximum dose attenuation of a single oblique field was reached to 8%, besides the largest difference between computed and measured doses for those posterior fields was within 1.7%. As a result, incorporating the accurate couch model in the TPS is necessary and adequate.

In this paper, we explored the effect of dose attenuation on four kinds of commonly used commercial treatment couches in IMRT and VMAT： Elekta iBEAM evo Couch、 Varian Exact Couch （ Standard Couch ） 、 Varian Exact IGRT Couch 、 BrainLAB imaging Couch .The study shown that the average dose attenuation range in the target was -0.72% ~ -3.15%, and the average dose attenuation is less obvious in 7F-IMRT and VMAT than in 5F-IMRT and 9F- IMRT because of the direction and weight of fields. The results of this study are consistent with those of others[16-20].

Usually speaking, a standard model of the treatment couches is often used to modify dose attenuation in commercial TPS. However, some treatment couches used in hospitals are not listed in the TPS catalog, which need to establish a actual model of treatment couch belonging to the hospital by users[14-15]. In the research of Aldosary[13], CT value (HU) was compared firstly between the fan beam CT (FBCT) and cone beam CT (CBCT) by scanning on Catphan 504 cylindrical phantom. Then the CBCT was used to scan the treatment couch. A model of treatment couch was created after the modification of HU values in the TPS. The dose attenuation of the treatment couch model established by this method is similar to the standard treatment couch model provided in the TPS catalog.

The daily records of Elekta Mosaiq system shown that coordinates of the treatment couch X, Y and Z changed every treatment ， which indicating there is a shift of the treatment couch relative to the patient's set-up position. Take x-coordinate for an example, the daily records shown the shift of the treatment couch ranged from -2.00 cm to +2.00 cm. This is due to changes of the patient's set-up position on the treatment couch in treatment. Consequently, the coordinates of the treatment couch changed. Simulation of treatment couch shift in the TPS showed that a treatment couch shift by 2 cm to the right or the left caused a maximum dose change of 0.65%,and an average dose change of less than 0.30%.This is due to the change range of the patient's set-up position was still within the dimension of treatment couch and the treatment couch surface is homogeneous. As result, the range of dose change is small.

Conclusions

The dose attenuation caused by the treatment couch is obvious in IMRT and VMAT. We should consider fully the necessity of incorporating the accurate couch model in the TPS to minimize dose difference between the computed dose in TPS and the delivered dose to patient in actual treatment. We still need to take attention that the average dose attenuation is less in 7F-IMRT and VMAT than in 5F- IMRT and 9F- IMRT for four kinds of commonly used commercial treatment couches, and Varian Exact Couch (Standard Couch) and Varian Exact IGRT Couch cause less average dose attenuation than Elekta iBEAM evo Couch and BrainLAB imaging Couch. The position of patients relative to the treatment couch, which often vary in daily set-up, but does not cause significant impact on the target dose in the treatment.

Disclosure conflict of interest

All the authors do not have any possible conflict of interest.

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