

Research/Technical Note

An Analysis Method of Dose Error Caused by the Couch Tilt of CT Simulation Machine

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Abstract: Purpose: If the horizontal plane is inconsistent between computer tomography (CT) couch and line accelerator (LA) couch, the position of the isocenter point in the radiotherapy treatment planning system (TPS) should deviate from that of it on the accelerator couch board. Then, the actual dose distribution was different from the radiotherapy plan we designed in TPS. This paper introduces a method to evaluate the dose deviation caused by the tilt of CT couch. Methods: We calculated the isocenter points of the position coordinates both in CT couch and LA couch, and compared the dose distribution when the two positions of isocenter points were applied in radiotherapy plan independently in TPS. The dose distribution difference of a breast radiotherapy plan was analyzed as a demonstration with this method. Results: The distance between the two isocenter positions increased with angle of CT couch. The tilt of the couch had an impact on the dose distribution, especially in larynx's maximum dose parameter. Conclusion: This method could quantitatively analyze the dose distribution deviation caused by the tilt of CT couch plate. The results can provide a valuable suggestion for clinical medical strategy.

Keywords: CT Couch, Line Accelerator Couch, Treatment Planning System, Isocenter Point

1. Introduction

In radiotherapy, the couch of computer tomography (CT) simulation machine and the couch of radiotherapy linear accelerator (LA) should be horizontal [1, 2]. Due to the aging of the CT machine, the CT couch might tilt. Then, the horizontal plane is inconsistent between CT couch and accelerator couch. This may cause the position of the isocenter point in the radiotherapy treatment planning system (TPS) was inconsistent with that of the isocenter point on the LA couch. Finally, the actual dose distribution may deviate from the radiotherapy plan's we designed [3]. In the study, we introduced a method to evaluate this dose deviation. And, according to an example of a breast cancer radiotherapy plan, we calculated the dose difference in this method for a specific analysis.

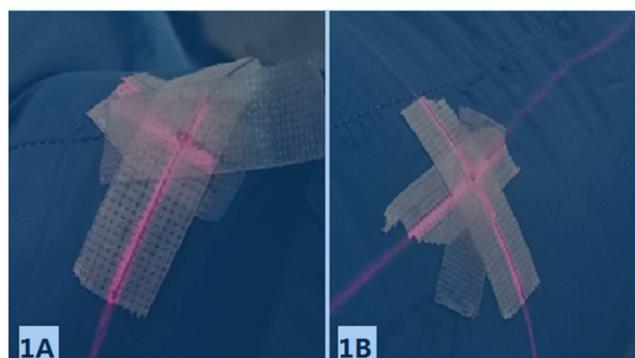


Figure 1. Red is the laser line; the blue line mark on the adhesive tape is based on the laser line; 1A is the right side of the patient; 1B is the left side of the patient, the lead point pasted on the adhesive tapes to mark the blue line cross center.

2. Materials and Methods

2.1. Data and Equipment

GE CT simulation machine (Lightspeed plus 4, General Electric Company, USA). Pinnacle 10.3 radiotherapy treatment planning system (Pinnacle 10.3, Philips, Netherlands). Elekta linear accelerator (Precise Treatment System, Elekta, Sweden).

Gammex laser positioning system (A3000A, Middleton, USA). All motion parameters met the requirements [4-9], except for the level of the CT couch.

Radiation imaging data of a patient with right breast cancer (female, 53 years old). Before treatment a written informed consent was obtained, and the procedures were conducted in accordance with the ethical standards of the institutional ethical committee. The patient was fixed in the vacuum mold.

2.2. Radiotherapy Procedure

The main process of radiotherapy includes: 1, Fixing the patient's body in the vacuum mold on CT couch, and the adhesive tapes with blue lines which were coincided with the laser lines were stuck on the vacuum mold [10-15], as shown in Figures 1, 2, Mark points (lead point) were stuck on the vacuum mold for indicating the center of the blue lines cross, then carry out the CT scanning. 3, Transmitting the CT images to the TPS. 4, Determining the position of the radiotherapy isocenter point according to the three lead points of the CT images, and the radiotherapy plan was designed based on the isocenter points, as shown in Figures 2, 5, After the acceptance of the plan, the patient was setup on the LA couch for treatment, as shown in Figure 3.

2.3. Description of the Isocenter Point Position

Because the horizontal plane was inconsistent between CT couch and accelerator couch. The laser lines cannot coincide with the blue lines cross marked in the adhesive tapes when setup on the LA couch [16, 17], as shown in Figure 3.

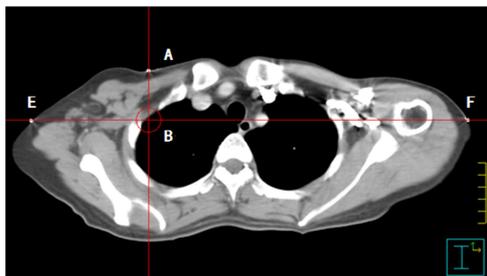


Figure 2. CT image with the lead point in TPS, red cross line is the positioning tool for isocenter point in TPS, point B is the isocenter point in TPS. Point E, A and F are the location of lead points.

The isocenter point in TPS was based on the center of the laser line cross which coincided with the lead point. However, on the LA couch, the isocenter point just can be located based on the center of the laser line cross, which do not coincide with the blue lines cross marked (or the lead point). Thus, the position of isocenter points were different between in TPS and

in LA couch. As a result, the actual dose distribution in LA was different from the plan we designed in TPS.

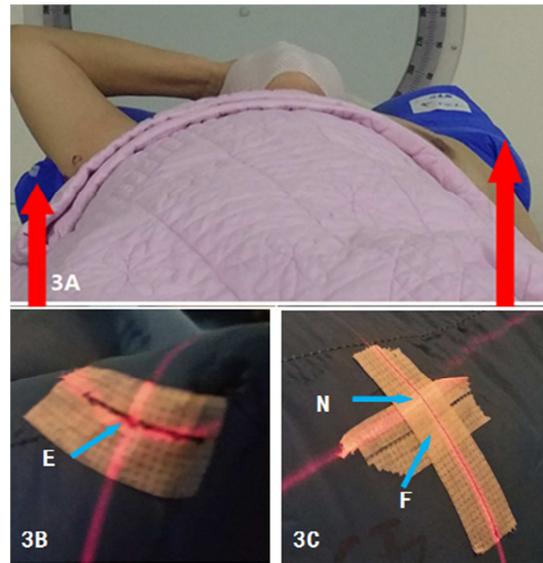


Figure 3. The setup diagram of LA treatment couch 3A: patient lying on accelerator treatment couch fixed in a vacuum mold. 3B: the detail view of laser cross line on the patient right side. 3C: the detail view of laser lines cross on the patient left side, N point is the laser cross point, F point is the blue line cross mark point on the adhesive tape.

2.4. Analysis of Isocenter Point Position

First of all, it should be clear that the external laser lines were horizontal both CT room and accelerator room. When the patient lying on the tilted CT couch plate, the two blue line cross points on adhesive tape (right and left) based on the external laser lines of CT room at the same level (or Point E and Point F are in a horizontal plane), as shown in Figure 3. However, when patient was lying on the accelerator couch in accelerator room, the two blue lines cannot match the external laser lines. The result was that the blue lines on adhesive tape were higher on one side and lower on the other side compared with the external laser lines. If we made the blue line match with the external laser line in patient right side, the external laser line was higher than the blue line in patient left side, as shown in Figure 3.

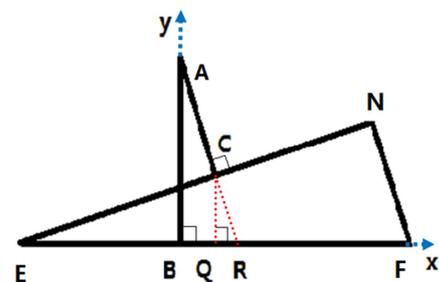


Figure 4. EF represents the couch surface level of CT; EN represents the couch surface level of accelerator; point A as shown in Figure 2. Point E represents blue line cross points on the patient's right side. Point F represents blue line cross points on the patient's left side in CT room. Point N represents external laser line cross points on the patient's left side in LA couch. Produce the line AC to R, line AC \perp line EN, line AB \perp line EF, line CQ \perp line EF, line EN \perp line NF.

We make a geometric diagram according to Figure 3, as shown in Figure 4. Then, EF represents the couch surface level of CT. EN represents the couch surface level of LA. Point A was shown in Figure 2. Point E represents blue lines cross point on the patient’s right side. Point F represents blue lines cross point on the patient’s left side in CT room. Point N represents external laser lines cross point on the patient’s left side in LA

$$x=(EB+ AB* \text{TAN}(\text{ASIN}(\text{NF}/\text{EF}))) * \text{COS}(\text{ASIN}(\text{NF}/\text{EF})) * \text{COS}(\text{ASIN}(\text{NF}/\text{EF})) -EB$$

$$y=(EB+ AB* \text{TAN}(\text{ASIN}(\text{NF}/\text{EF}))) * \text{COS}(\text{ASIN}(\text{NF}/\text{EF})) * (\text{NF}/\text{EF})$$

The distance between Point B and Point C is: $\sqrt{x^2 + y^2}$.

room. Then, the Point B was the isocenter point in TPS, the Point C was the isocenter point on the LA couch as actual setup.

In Figure 4, assuming that Point B is taken as the origin for a plane coordinate system xBy, and the coordinate value of Point C in this coordinate system is (x, y). According to the geometric relationship, we can get:

(CTV), Planning Target Volume (PTV), bone, larynx.

2.5. Analysis Method of the Different Distribution

In TPS, we named the radiotherapy plan designed in TPS as the original plan, which the isocenter point was Point B. Then, we move the isocenter point of the original plan from Point B to Point C, and the new plan was named as the simulated plan. All parameters of the two plans are the same except for the isocenter point and fields angle. All fields angle in the simulated plan is $\angle CAB$ smaller than that in the original plan. Take a breast radiotherapy plan as an example, dose parameters difference between the two plans were compared and analyzed, including: lung, cord, clinical target volume

3. Results

In TPS, EF=353mm, EB=95mm, AB=42mm and NF=4mm are measured. According to the formula, the coordinates of Point C are: x=0.46, y=1.08; $\angle CAB=0.65^\circ$. Field angles were reduced by 1 degree in the simulated plan compared with the original plan (Pinnacle 10.3 TPS only supports the modulation of the integer value of the field). The dose difference between the simulated plan and the original planned is shown in Table 1.

Table 1. Dose comparison between simulated plan and original plan.

		Min.	Max.	Mean.	ΔMin. %	ΔMax. %	ΔMean. %
Larynx	simulated plan	546.6	4916.3	2258.6	1.66%	6.33%	0.05%
	original plan	537.7	4885.4	2257.6			
L Bone	simulated plan	259.0	4577.3	2101.0	-3.47%	-0.96%	-1.86%
	original plan	268.3	4621.8	2140.2			
CTV	simulated plan	4766.8	5785.0	5303.2	-0.61%	0.62%	0.47%
	original plan	4796.2	5749.2	5278.2			
PTV	simulated plan	4273.9	5785.0	5262.1	-1.23%	0.62%	0.41%
	original plan	4327.2	5749.2	5240.5			
Spinal cord	simulated plan	178.9	2695.0	1391.5	1.88%	0.40%	-1.19%
	original plan	175.6	2684.2	1408.3			
RRV cord	simulated plan	137.0	3066.0	1341.2	1.18%	0.37%	-0.86%
	original plan	135.4	3054.8	1352.8			
R lung	simulated plan	5.2	5486.3	491.6	1.96%	0.42%	-0.14%
	original plan	5.1	5463.6	492.3			
L lung	simulated plan	2.4	1666.5	88.3	4.35%	-1.61%	4.87%
	original plan	2.3	1693.8	84.2			

Note: Min. is the minimum dose, in cGy; Max. is the maximum dose, in cGy; Mean. is the average dose, in cGy; PRV cord is the outline of the cord with an external expansion of 5mm. ΔMin.% is the difference percentage between the simulated plan and the original plan, and the calculation method is: (simulated plan-original plan) / original plan * 100%; the calculation methods of ΔMax.% and ΔMean.% are in accordance with ΔMin.%.

When maintaining same values of the EF, EB and AB, if the NF changes, the relationship between the distance between Segment BC and the $\angle CAB$ are shown in Table 2.

Table 2. The relationship for the BC, $\angle CAB$ and the NF.

NF (mm)	Segment BC distance (mm)	$\angle CAB$ (°)
1	0.29	0.16
2	0.59	0.32
3	0.88	0.49
4	1.18	0.65
5	1.47	0.81
10	2.94	1.62
20	5.88	3.25

4. Discussion

Radiotherapy was based on high-value medical equipment such as CT machine and linear accelerator [18, 19]. Generally, it might take many years for these devices to be updated. If an equipment fails and needs to be repaired after years of service, the maintenance might not be responded in time due to the shortage of accessories, etc. For the CT machine, the horizontal level of the CT couch is reduced due to long-term wear caused by multiple movements. If the tilt of the CT couch cannot be corrected immediately, it was important how to evaluate the effect on dose and whether to continue radiotherapy [2, 3].

In the literature, more reports were the influence of CT couch plate on the dose for the attenuation of the material to the radiation [3, 20]. Although there were many maintenance reports for the CT couch plate movement failure, the study and analysis of dose error due to the CT couch tilt was rare.

In this study, we introduce a method to evaluate the effect of the CT couch tilt on the dose distribution. We think that this method could achieve the purpose of evaluating dose error due to CT couch tilt. The results can provide a valuable suggestion for clinical medical strategy: whether the radiotherapy plan should be implemented or not. For all that, it must be made clear that this method was only an auxiliary method. Correcting and repairing the CT couch immediately always be the first step.

It should be pointed out that the method assumes that the patient is treated as a rigid body and the position, volume and shape changes of the organ are ignored; at the same time, it assumes that the tilt angle of the couch plate is consistent, which does not change with the moving of the couch.

5. Conclusion

The tilt of the CT couch leads to the change of the isocenter point position, which will eventually lead to the dose difference between the LA couch and the CT couch. In this study, we recommended a specific method to evaluate this dose difference. This method could quantitatively analyze the dose distribution deviation caused by the tilt of CT couch plate, and the results of dose analysis provide a valuable suggestion for clinical medical strategy.

Conflict of Interest

The authors declare that they have no competing interests.

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