


# Dosimetric Evaluation of the QFix kVue™ Calypso Couch Top

Lingtong Hou, MS<sup>1</sup>, Huiqin Zhang, MS<sup>2</sup>, Xiaomei Sun, PhD<sup>3</sup>,  
Qianqian Liu, MS<sup>1</sup>, Tingfeng Chen, PhD<sup>1</sup>, Yong Liu, PhD<sup>1</sup>,  
Xiaodong Jiang, PhD<sup>2</sup>, and Shengyu Yao, MS<sup>1</sup> 

Technology in Cancer Research & Treatment  
Volume 20: 1-10  
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DOI: 10.1177/15330338211011964  
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## Abstract

**Purpose:** To evaluate the dosimetric accuracy of the default couch model of the QFix kVue™ Calypso couch top in the treatment planning system. **Methods:** With the gantry 180°, field size 20 × 20 cm, 6 MV, we measured the depth dose, off-axis dose, and dose plane of different depths in the phantom with the couch rails in and out, respectively. Isocenter doses at different angles were also obtained. The results were compared to the doses calculated using the default couch top model and the real scanned couch top model. Then we revised the default model according to the measured results. **Results:** With “Rails In,” the depth dose, off-axis dose, and dose plane of the default couch top model had a big difference with the dose of the real scanned couch top model and the measured result. The dose of the real scanned couch top model was much closer to the measured result, but in the region of the rail edge, the difference was still significant. With “Rails Out,” there was a minor difference between the measured result, the dose of the default couch top model and the real scanned couch top model. The difference between the measurement and the default couch top model became very small after being revised. **Conclusions:** It is better to avoid the beam angle passing through the couch rails in treatment plans, or you should revise the parameter of the QFix kVue™ Calypso couch top model based on the measured results, and verify the treatment plan before clinical practice.

## Keywords

Calypso, couch rails, default model, dosimetric accuracy, model revision

## Abbreviations

AAA, analytic anisotropic algorithm; CBCT, cone beam computed tomography; CT, computed tomography; DCT, default couch top model; DD, depth dose; EPID, electronic portal imaging system; MLC, multi-leaf collimator; MU, monitor unit; RCT, real scanned couch top model; SRS, stereotactic radiosurgery; SSD, source-to-phantom surface distance; SBRT, stereotactic body radiation therapy; TPS, treatment planning system.

Received: September 21, 2020; Revised: January 25, 2021; Accepted: March 29, 2021.

## Introduction

Radiation therapy is an important part in tumor therapy. Stereotactic radiosurgery (SRS) and stereotactic body radiation therapy (SBRT) technologies have proved to be as effective as surgery in some early-stage tumors.<sup>1</sup> SRS and SBRT technologies rely much on the precise image-guided devices to accurately track the movement and change of the tumor, ensuring that the lethal dose falls within the tumor rather than within the surrounding normal tissues.

The Edge linear accelerator (Varian Medical Systems, Palo Alto, CA) is a dedicated stereotactic suite involving high dose rate mode and several high precision components such as

<sup>1</sup> Department of Radiation Oncology, Shanghai General Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China

<sup>2</sup> Department of Oncology, The Affiliated Lianyungang Hospital of Xuzhou Medical University, Lianyungang, China

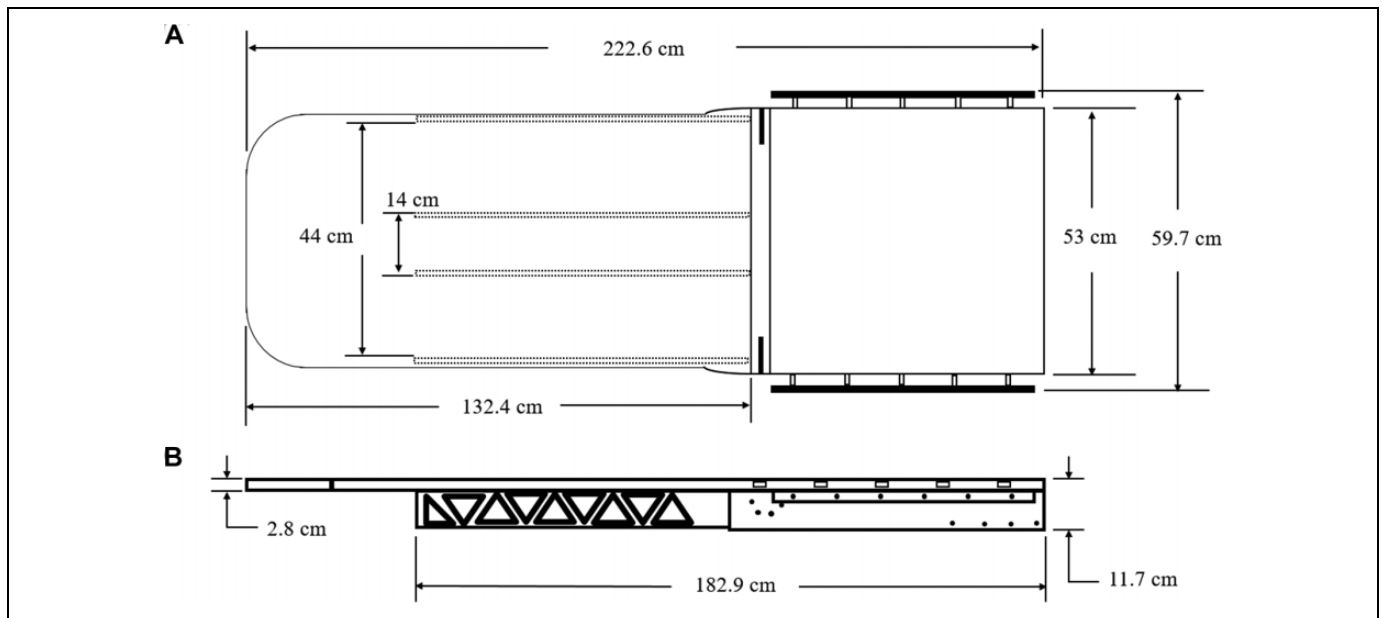
<sup>3</sup> Department of Gynecology, Obstetrics and Gynecology Hospital, Fudan University, Shanghai, China

### Corresponding Authors:

Shengyu Yao, MS, Department of Radiation Oncology, Shanghai General Hospital, Shanghai Jiao Tong University School of Medicine, No. 100 Haining Road, Hongkou District, Shanghai 200080, China.  
Email: jordanyao11@126.com

Xiaodong Jiang, PhD, Department of Oncology, The Affiliated Lianyungang Hospital of Xuzhou Medical University, Lianyungang 222000, China.  
Email: jxdpaper@163.com





**Figure 1.** Structure of the QFix kVue™ Calypso couch top: (A) vertical view and (B) sagittal view.

six-dimensional couch top and high-definition MLC.<sup>2-5</sup> In terms of image guidance components, in addition to the conventional precision radiotherapy system such as kV-CBCT,<sup>6</sup> MV-EPID,<sup>7</sup> EDGE is also equipped with the Calypso system (Calypso Medical Technologies, Inc., Seattle, WA), which is a 4D real-time electromagnetic tracking system monitoring the position of implanted transponders during treatment.<sup>8-10</sup> To avoid interference with electromagnetic signals, a non-conductive couch top with supporting rails (QFix kVue™ Calypso couch top) is installed.<sup>11,12</sup>

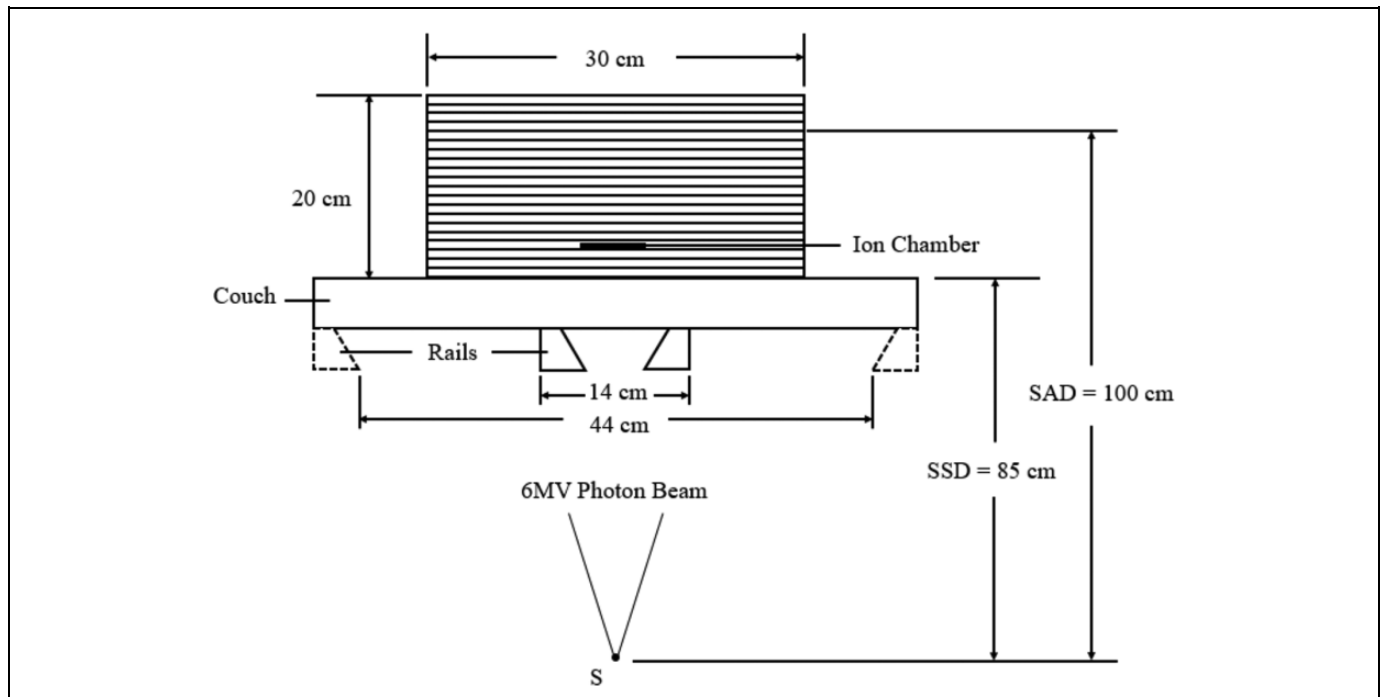
As the AAPM Task Group 176 (TG-176) reported, the dosimetric effect of the support structure to the patient is very complex, which can increase the surface dose, decrease the tumor dose, and change the overall dose distribution.<sup>13</sup> Therefore, the couch top must be modeled in the treatment planning system (TPS) and be considered in dose calculations. Eclipse v.13.6 has a default model of the QFix kVue™ Calypso couch top, users can insert the default model to patients' CT images when designing treatment plans. Gardner et al studied the creation and implementation of the QFix kVue™ couch top TPS model and evaluated it in 6 FFF and 10 FFF photon beams. Their result showed that compared to without accounting for the couch top in dose calculation, it significantly reduced the deviation from the actual dose delivered in patients, which resulted in higher precision dose calculation by using a self-build couch top model.<sup>14</sup> However, for most radiotherapy centers, there are certain difficulties in building a couch top model by themselves, so Eclipse built a default model for QFix kVue™ Calypso couch top after the 13.0 version, users can generally use the default model in dose calculation.<sup>15,16</sup> However, there is no independent study that validated the dosimetric accuracy of the default model. It may cause a large error if the default couch model is used for dose calculation without verification.

This study detailed the evaluation and revision of the default model of the QFix kVue™ Calypso couch top. The evaluation of the default model, including the CT scan of the couch top, dose calculation in TPS, and comparing dose distribution with the actual measurements, was described in the Materials and Methods section. Not only depth dose but also off-axis dose, dose plane, and isocenter dose were analyzed during the evaluation process. The revision was by changing the parameter of the default couch top model, which has better feasibility compared with the self-build model.

This study showed that the calculated dose with the default model of QFix kVue™ Calypso couch top has a significant difference compared with the actual measurement, so users should be cautious about using it in clinical practice before revised.

## Materials and Methods

The QFix kVue™ Calypso couch top is specially designed for the Calypso system. It consists of a high strength fiber insert and two supporting rails. The materials of all components are free of metal and non-conductive to avoid interference with electromagnetic signals. The insert is 132.4 cm long, 53 cm wide, and 2.8 cm thick as shown in Figure 1. The rail system utilizes a periodic lattice structure to minimize imaging artifacts. The rails can slide freely in the lateral direction, but only two configurations of "Rails In" and "Rails Out" are used for the convenience and controllability of clinical operation. With "Rails In" configuration, the outer edge of the rails spans a lateral distance of 14 cm. With "Rails Out" configuration, the inner edge of the rails spans a lateral distance of 44 cm (see Figure 1 for dimensions of couch top and rails configurations). There are two default models for this couch top in Eclipse TPS, corresponding to configurations of "Rails In" and "Rails Out,"



**Figure 2.** Phantom setup for measuring depth dose when the gantry angle was  $180^\circ$ . The rails have two measurement positions (solid line: “Rails In”; dash line: “Rails Out”).

respectively. The default couch model in TPS has three adjustable parameters, which are the HU values of couch interior, couch surface, and couch support rails. The default parameter values are as follows: Couch Interior:  $-1000$  HU, Couch Surface:  $-300$  HU, Couch Support Rails:  $200$  HU.

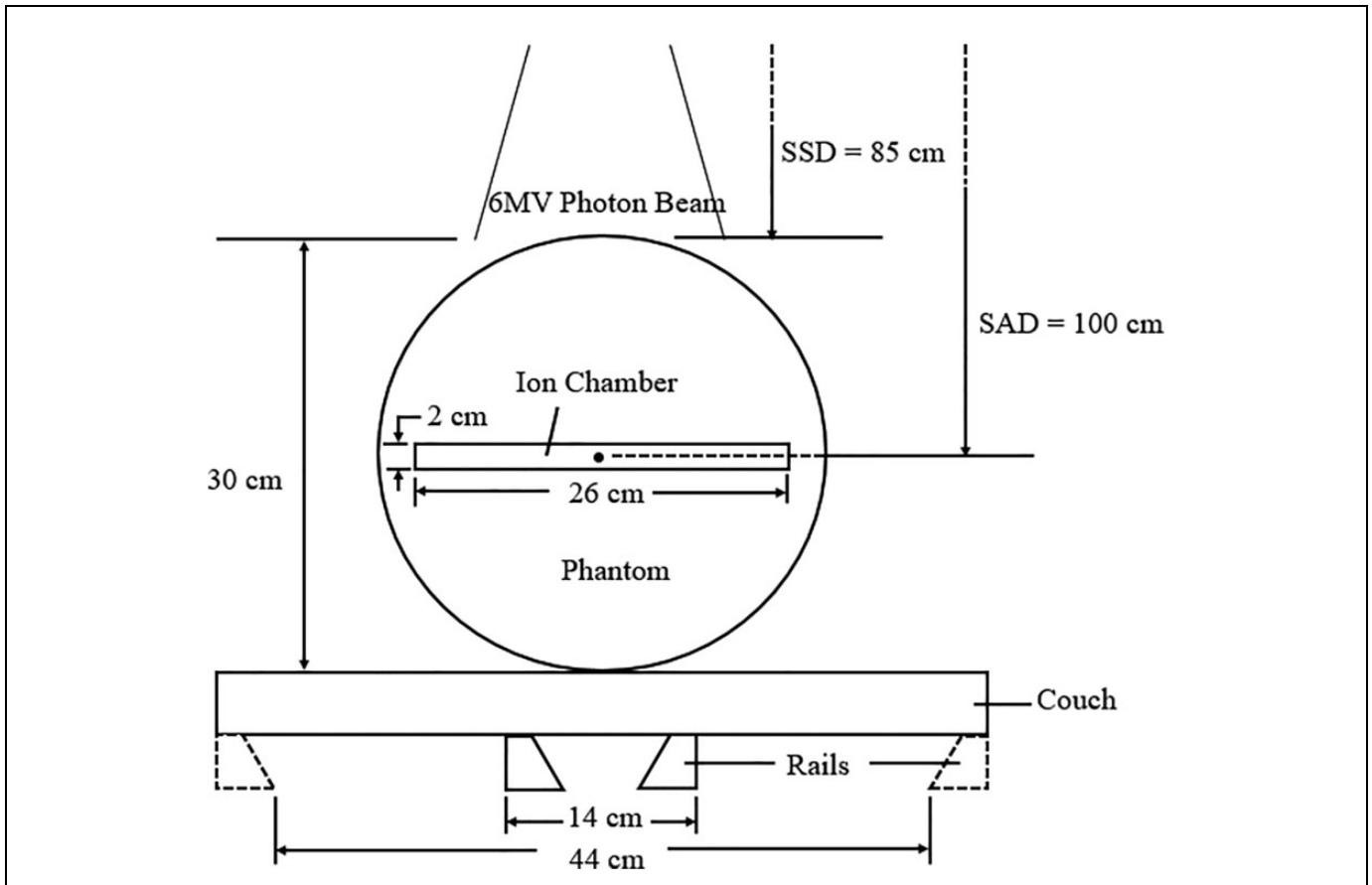
In this section, RW3 (Polystyrene with 2%  $\text{TiO}_2$  by weight) slab phantom which size was  $30 \times 30 \times 20$  cm and 23 plates with a various thickness (0.1, 0.2, 0.5, and 1.0 cm) were used to evaluate the central axis attenuation of the couch top for 6 MV photon beams.<sup>17,18</sup> A parallel-plate ion chamber (PTW ROOS-34001) was used due to its high resolution in measuring the superficial dose.<sup>19</sup> PTW ROOS-34001 is recognized as the standard ion chamber for electron beam measurement and is also suitable for photon beam measurement. The beam size was set to  $20 \times 20$  cm to cover the rails with “Rails In” configuration.<sup>20</sup> And with “Rails Out,” the rails had no impact on the dose distribution because they were out of the beam field. The source-to-phantom surface distance (SSD) was set to 85 cm. By varying the position of the ion chamber in the phantom, a depth dose (DD) curve of the central axis was acquired for each configuration of rails, with gantry at  $0^\circ$  and  $180^\circ$ , respectively. Figure 2 showed the setup of the phantom when the gantry angle was  $180^\circ$ . The measurement step length was 0.1 cm within the buildup region and 1 cm after it. 200 monitor units (MUs) were delivered to each position.

The OCTAVIUS Detector 1500 (OD1500) array was used for the off-axis dose and dose plane measurement to evaluate the dosimetric effect of the couch rails. It consists of 1405 vented ionization chambers, each chamber has an entrance area of  $4.4 \times 4.4$  mm<sup>2</sup> and a height of 3 mm, resulting in an

ionization volume of 0.058 cm<sup>3</sup>.<sup>21-23</sup> The chambers are arranged in rows, and the center-to-center distance between the chambers in each row is 7.07 mm. The water effective depth from the surface to the detector array is 7 mm. Off-axis dose and dose plane at depths of 1 cm, 5 cm, and 10 cm were measured by changing the thickness of the RW3 slab phantom.

The OCTAVIUS motorized cylindrical polystyrene phantom (embedded with OD1500 array), was used to measure the isocenter doses and treatment plans at different angles. Its capability to rotate synchronously with the gantry, in terms of angle and rotation speed as in the real planned treatment, is made possible, thanks to an inclinometer that is set on the gantry and that is connected to a control unit that transfers the movement information to the phantom and acquires dosimetric data every 200 ms. The beam always hits the detector array in a perpendicular way because the same face of the detector follows the gantry.<sup>24</sup> Different angle intervals were selected according to the relative position of the beam field and the couch rails. Specifically, an interval of  $10^\circ$  was used for the gantry at  $120^\circ$ - $240^\circ$  (clockwise), and  $30^\circ$  interval for the rest part. Figure 3 showed the setup of the phantom when the gantry angle was  $0^\circ$ .

We disassembled the QFix kVue<sup>TM</sup> couch top and scanned it with the RW3 phantom in our GE590RT CT scanner, with “Rails In” and “Rails Out,” respectively. The relevant scan parameters utilized include 600 mm FOV, 2.5 mm slice thickness, 120 kVp, and 400 mAs. These two CT image series (“Rails In” and “Rails Out”) were imported into Eclipse v.13.6, referred to as Real Scanned Couch Top Model (RCT). The phantom without the QFix kVue<sup>TM</sup> Calypso couch top was



**Figure 3.** Phantom setup for measuring isocenter dose when the gantry angle was  $0^\circ$ . The rails have two measurement positions (solid line: “Rails In”; dash line: “Rails Out”).

scanned in the same way and the images were also imported into TPS. The default couch top with “Rails In” or “Rails Out” was referred to as Default Couch Top Model (DCT). We measured the HUs of different parts of the couch top, and the HUs of the default couch top model were set as follows: Couch Interior:  $-930$  HU, Couch Surface:  $-450$  HU, Couch Support Rails:  $250$  HU, which was almost the same as Gardner reported.<sup>14</sup> The dose calculation algorithm was analytic anisotropic algorithm (AAA) and the calculation grid resolution was  $0.25$  cm.<sup>25,26</sup>

The DD and Off-axis dose difference between the calculation and the measurement was calculated as followed:  $[d = \frac{D_{cal} - D_{mea}}{D_{mea}} \times 100\%]$ , where  $D_{cal}$  was for the dose calculated in RCT or DCT,  $D_{mea}$  was for the dose measured in phantom. And we used the  $\gamma$  analysis to compare the dose distribution measured and calculated in TPS.<sup>27</sup> The  $\gamma$  analysis criteria were  $3$  mm,  $3\%$ , and  $10\%$  thresholds. Then revised the default model according to the measurement results until the deviation between the calculation result and the measurement met the clinical requirement.

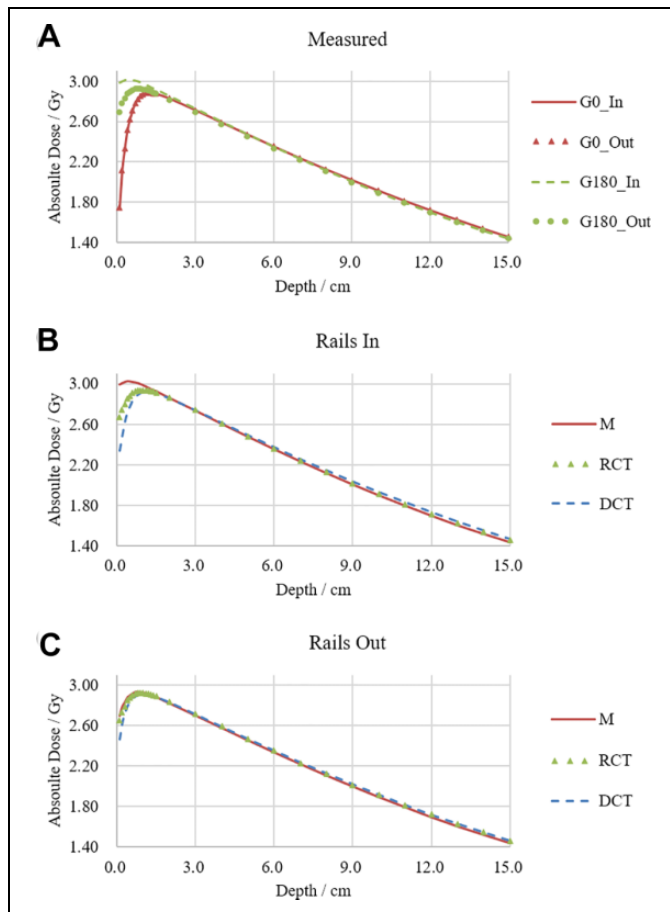
## Results

### Comparison of the Depth Dose

The depth dose from  $0$  to  $15$  cm in the phantom at gantry  $0^\circ$  and gantry  $180^\circ$ , with “Rails In” and “Rails Out” were measured

and compared. The results were shown in Figure 4A. When the gantry angle was  $0^\circ$ , the depth doses of “Rails In” and “Rails Out” had no difference. When the gantry angle was  $180^\circ$ , with “Rails Out,” the surface dose increased obviously compared to the gantry  $0^\circ$ , it was increased by  $54.6\%$  at the depth of  $1.1$  mm, and the depth of maximum dose moved to the surface about  $5$  mm. This was mainly caused by the effect of the couch surface. The dose at gantry  $180^\circ$  was higher than gantry  $0^\circ$  from  $0$  to  $2$  cm, and after  $2$  cm, due to the attenuation of the couch surface, it became lower and reduced up to  $1.8\%$  at  $15$  cm; with “Rails In,” the surface dose was even higher, it was increased by  $71.4\%$  at the depth  $1.1$  mm, and the depth of maximum dose moved to surface about  $8$  mm. The dose at gantry  $180^\circ$  was higher than gantry  $0^\circ$  until  $4$  cm, after  $4$  cm it became lower, and reduced up to  $2.2\%$  at  $15$  cm.

We also compared the measured dose with the calculated doses of RCT and DCT. Figure 4B and Figure 4C showed the comparison curves with “Rails In” and “Rails Out,” respectively. As can be seen from both figures, before the maximum dose depth, both the calculated doses of the two models were lower than the measured dose, and the curve of RCT was closer to the measurement curve. At the depth of  $0.11$ ,  $0.51$ ,  $1.01$  cm, when the rails were in, the dose of RCT was reduced by  $10.73\%$ ,  $4.58\%$ , and  $1.51\%$ , and the dose of DCT was reduced

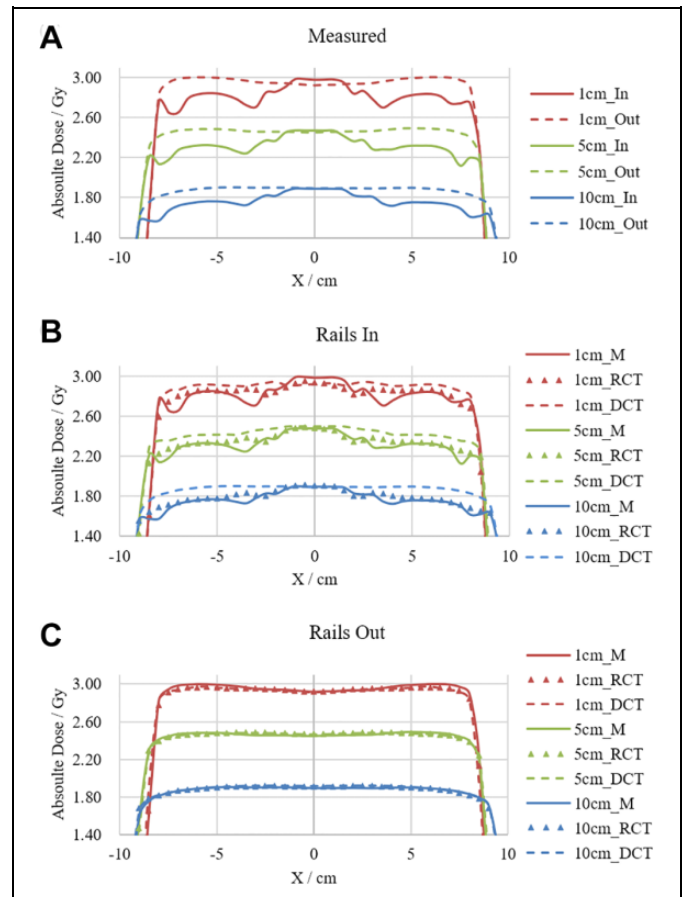


**Figure 4.** Depth doses comparison: (A) the measured depth dose with “Rails In” and “Rails Out,” at 0° and 180°; (B) the depth doses of measured, scanned model and default model with “Rails In” at 180°; (C) the depth doses of measured, scanned model and default model with “Rails Out” at 180°. M indicates the measured result; RCT, the calculated result of the real scanned couch top model; DCT, the calculated result of the default couch top model.

by 21.66%, 7.86%, and 2.16% respectively; when the rails were out, the dose of RCT was reduced by 1.60%, 0.77%, and 0.06%, and the dose of DCT was reduced by 8.47%, 2.11%, and 0.28% respectively. After the maximum dose depth, the calculated dose became slightly higher than the measured dose, and the deviation became larger as the depth increased. At the depth of 5, 10, 15 cm, with “Rails In,” the dose of RCT was increased by 0.3%, 0.85%, and 1.44%, and the dose of DCT was increased by 0.80%, 2.01%, and 2.61% respectively; with “Rails Out,” the dose of RCT was increased by 0.74%, 1.07%, and 1.7%, and the dose of DCT was increased by 0.75%, 1.47%, and 1.93% respectively.

### Comparison of the Off-Axis Dose

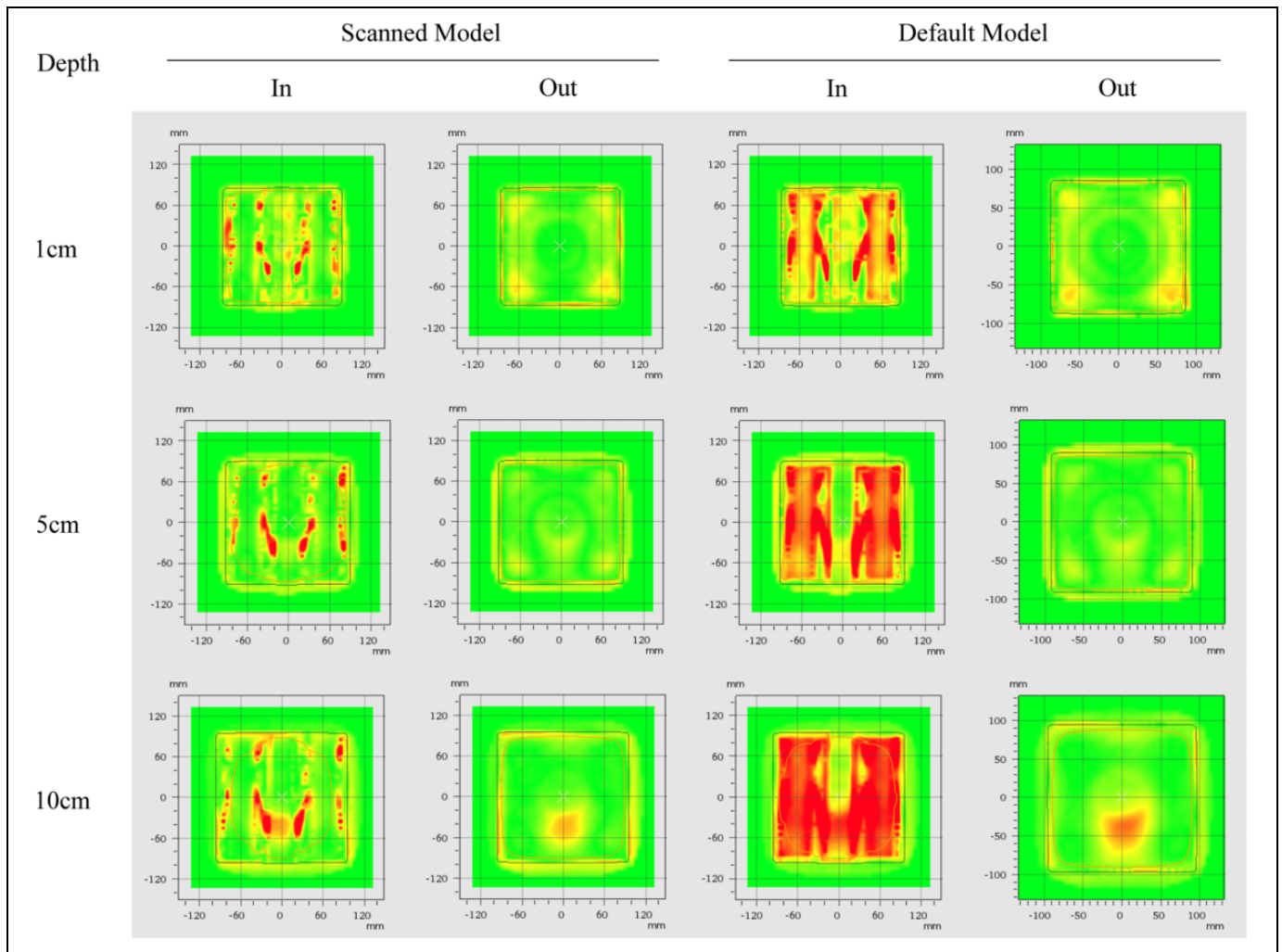
Measured off-axis doses of “Rails In” and “Rails Out” at 1 cm, 5 cm, and 10 cm were shown in Figure 5A. With “Rails In,” at the flat-portion of the rails, due to the attenuation of the rails, the dose was significantly lower than that with “Rails Out,” and



**Figure 5.** Off-axis doses comparison: (A) the measured off-axis doses with “Rails In” and “Rails Out”; (B) the off-axis doses of measured, scanned model and default model with “Rails In”; (C) the off-axis doses of measured, scanned model and default model with “Rails Out.” M indicates the measured result; RCT, the calculated result of the real scanned couch top model; DCT, the calculated result of the default couch top model.

the maximum attenuation can reach up to 5.46%, 6.68%, and 7.07% at the depth of 1 cm, 5 cm, and 10 cm, respectively. At the edge of the rails, the attenuation became much higher, and the maximum attenuation can reach up to 9.95%, 10.98%, and 13.09% at the depth of 1 cm, 5 cm, and 10 cm, respectively.

The Off-axis dose comparison between the calculation and the measurement was shown in Figures 5B and 5C. In Figure 5B, with “Rails In,” the dose of DCT still had a significant difference compared to the measurement, whatever at the flat portion or the edge-portion of the rails, the max deviation can be up to 2.71%, 3.88%, and 7.52% at the depth of 1 cm, 5 cm, and 10 cm in the flat-portion. And at the edge-portion, the deviation was even higher, it can be up to 7.36%, 10.07%, and 13.41% at the depth of 1 cm, 5 cm, and 10 cm. The dose of RCT was much closer to the measurement, at the flat-portion, the deviations were all less than 1%, but at the edge-portion, the difference was still significant, it can be up to 5.42%, 6.27%, and 7.25% at the depth of 1 cm, 5 cm, and 10 cm. In Figure 5C, with “Rails Out,” there was little difference between the



**Figure 6.** Dose plane comparison between the calculations of the two models and the measurement at different depths. The red area is where  $\gamma > 1$ .

calculated dose of the two models and the measurement, the max deviation at the depth of 1 cm, 5 cm, and 10 cm was  $-2.00\%$ ,  $1.06\%$ , and  $1.32\%$  between the dose of RCT and the measurement, and  $-2.55\%$ ,  $1.06\%$ , and  $1.91\%$  between the dose of DCT and the measurement, respectively.

### Comparison of the Dose Plane

Dose plane comparison at different depths as shown in Figure 6 (Measured vs RCT- left 2 columns; Measured vs DCT- right 2 columns),  $\gamma$  analysis was used to evaluate the difference,  $\gamma > 1$  means fail (red part in figure). With “Rails In,” the passing rates of RCT were much higher than that of DCT. The failed parts of RCT were mainly in the edge of the rails, but for DCT, the failed parts were both in the edge and the flat portion of the rails. With “Rails Out,” the calculated doses of the two models were in good agreement with the measurement in the whole field. The  $\gamma$  passing rates were listed in Table 1. With “Rails In,” all the  $\gamma$  passing rates were above 90% for RCT; for DCT, the rates were much lower and getting worse with the depth

**Table 1.**  $\gamma$  Passing Rates Comparison at Different Depth.

| Depth/cm | $\gamma$ passing rate/% |        |               |        |
|----------|-------------------------|--------|---------------|--------|
|          | Scanned model           |        | Default model |        |
|          | In                      | Out    | In            | Out    |
| 1        | 92.10                   | 100.00 | 78.80         | 100.00 |
| 5        | 93.60                   | 100.00 | 55.60         | 100.00 |
| 10       | 93.60                   | 100.00 | 48.70         | 98.10  |

increased. With “Rails Out,” the  $\gamma$  passing rates were all 100% except the result of 10 cm of DCT.

### Isocenter Dose at Different Angles

The isocenter doses at different angles, with “Rails In” and “Rails Out” were shown in Figure 7. It was found that the couch top and the couch rails have different degrees of attenuation effects on the 6MV photon beam. The total attenuation

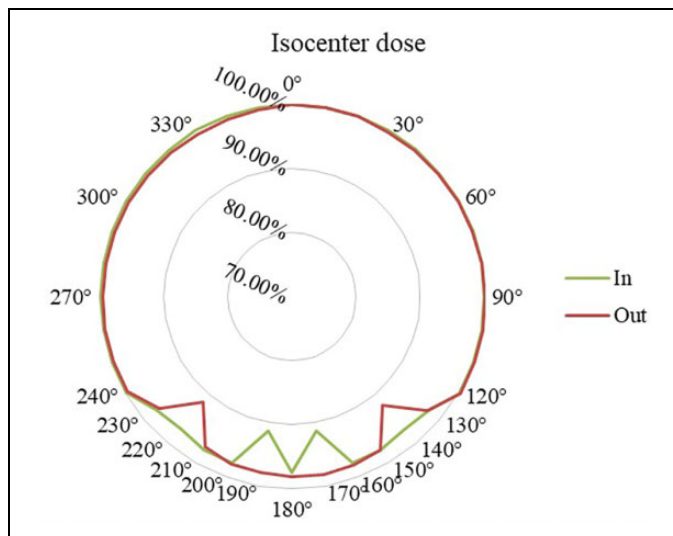
percentage ranged from 2.55% to 8.79% with “Rails In,” and from 1.84% to 8.50% with “Rails Out.” In general, the attenuation percentage resulted from the couch top was about 2.14%, and about 6.00% for the couch rails. The affected angle range was 120-240°(clockwise), the maximum attenuation angle range was from 160° to 180°, 180° to 200° with “Rails In,” and from 130 to 150°, 210° to 230° with “Rails Out.” Specifically, when the gantry was at 180°, 190°, 200°, 210°, 220°, 230°, the attenuation percentage was 2.55%, 8.79%, 2.41%,

2.41%, 2.98%, 2.41% with “Rails In,” and 1.84%, 2.12%, 2.27%, 2.83%, 8.50%, 2.83% with “Rails Out.”

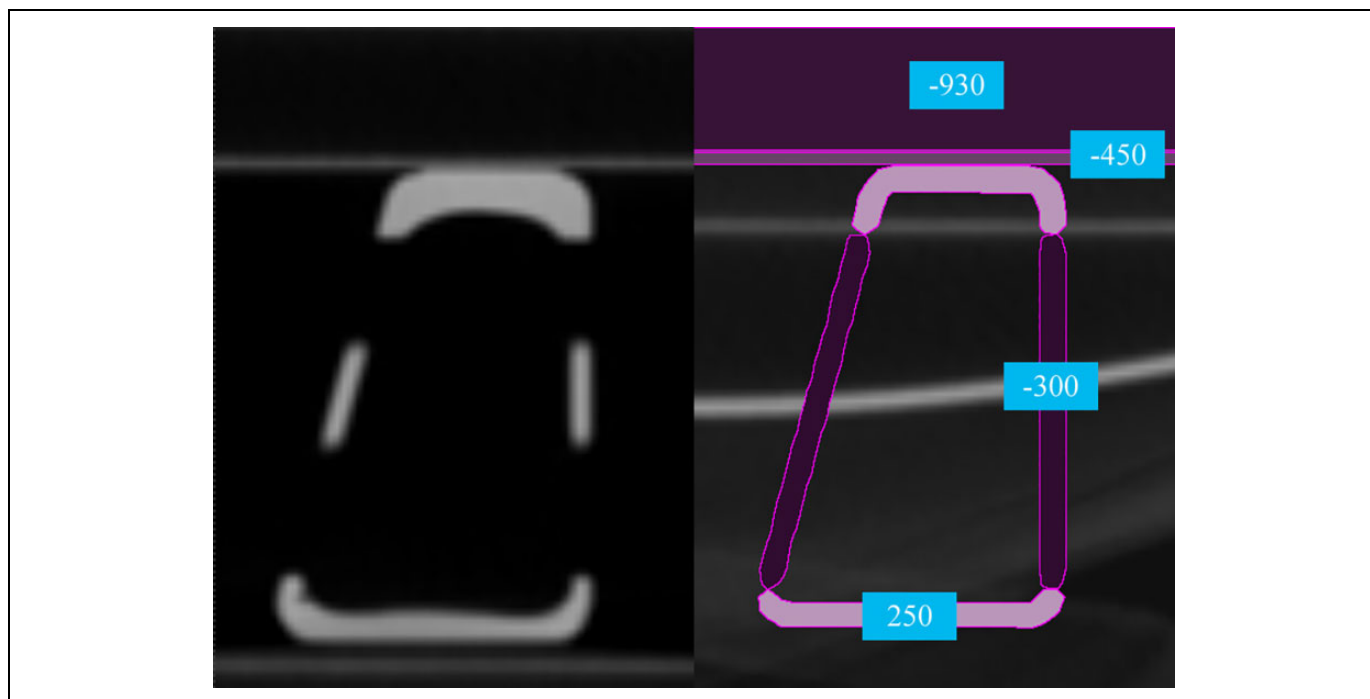
### Revision of the Default Model

Based on the above results, it was better not to use the default couch top model in clinical practice before revised. In this study, the “Rails In” configuration was selected to maximize the available gantry clearance and minimize oblique beam transmission through the rails.

The edge-portion of the couch rails in the default model was a consistent structure rather than a periodic lattice structure (see Figure 8), and the HU of this portion cannot be edited when inserting it into a CT image, and the default HU was -1000. But after inserted, the HU of the edge-portion can be revised manually. In this research, it was changed from -1000HU to -700HU, -500HU, -300HU, -100HU, respectively. It was found that the calculated result was significantly improved, and the dose at the edge of the rails was gradually approaching the measured result. Among them, it performed best when the parameter was -300HU (see Table 2). The deviation of depth dose between DCT and the measurement was within 1% at different depths. And the dose distribution at both the flat-portion and the edge-portion of the rails was better. The deviation was reduced from 2.71%-7.52% to 2.64%-3.49% at the flat-portion, and from 7.36%-13.41% to within 4.75% at the edge-portion (see Figure 9). The  $\gamma$  passing rate of the dose plane comparison was also increased significantly, from 78.8%, 55.6%, and 48.7% to 89.2%, 92.4%, and 95.2% at the depth of 1 cm, 5 cm, and 10 cm, respectively. The



**Figure 7.** Isocenter dose comparison between “Rails In” and “Rails Out.”



**Figure 8.** Structure comparison between the scanned model and default model of the rails (left side is the scanned model, right side is the default model), the values in the figure were the revised HUs used in this research.

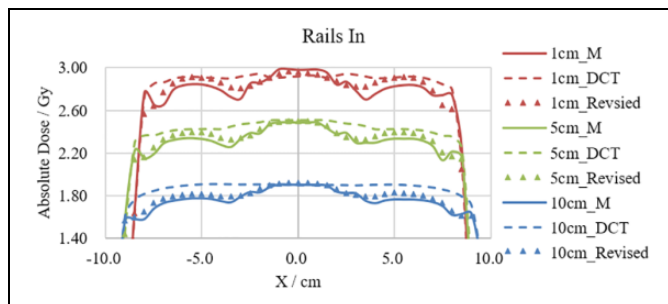
$\gamma$  passing rate of treatment plans with square field  $20 \times 20 \text{ cm}^2$  at different angles was also measured, and the results were shown in Figure 10, the revised model performed much better.

## Discussion

As reported in RTP 176, the supporting couch top will increase the body surface dose, decrease the target dose, and change the overall dose distribution. It is necessary to consider the effect

**Table 2.**  $\gamma$  Passing Rates Comparison of the Default Model and Revised Model at Different Depth.

| Depth/cm | $\gamma$ passing rate/% |        |               |        |        |
|----------|-------------------------|--------|---------------|--------|--------|
|          | Default model           |        | Revised model |        |        |
|          | -1000HU                 | -700HU | -500HU        | -300HU | -100HU |
| 1        | 78.80                   | 90.30  | 89.40         | 89.20  | 81.30  |
| 5        | 55.60                   | 89.70  | 92.10         | 92.40  | 88.60  |
| 10       | 48.70                   | 74.80  | 94.60         | 95.20  | 91.70  |



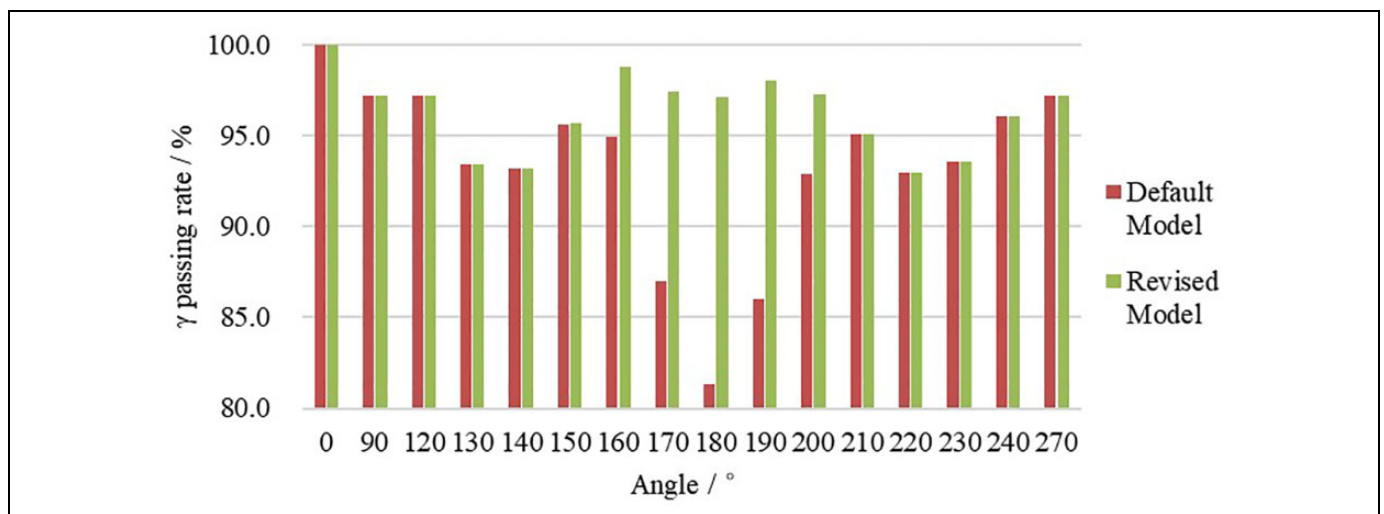
**Figure 9.** Off-axis dose comparison between the measurement and the calculations of the revised model and default model at different depths. M indicates the measured result; DCT, the calculated result of the default couch top model; Revised, the calculated result of the revised couch top model.

of the couch in radiotherapy, and couch models should be created and calculated in TPS. The QFix kVue<sup>TM</sup> Calypso couch top is composed of a fiber surface, a filler, and two supporting rails, the structure is more complex than other couch tops. Thus, before clinical use, the dose distribution of the couch top and the dosimetric accuracy of the default model should be evaluated.

The couch surface will increase the dose at the contact surface. Meara et al found that the maximum dose can be increased by 47% to 56% with different couch tops;<sup>28</sup> Butson et al found that the skin dose (defined at a depth of 0.15 mm) is increased by 55% with the Varian Exact<sup>TM</sup> couch top for the 6MV photon beam with a size of  $10 \times 10 \text{ cm}$ .<sup>29</sup> The skin dose measured in this study (at the depth of 1.1 mm) is increased by 71.4% with “Rails In” and 54.6% with “Rails Out.” The presence of the supporting rails in the beam field increases the surface dose in the central axis, due to the scattering dose of the rails.

A few literature had reported the attenuation effect of the couch top. These studies found that the attenuation ranged from 1% to 5% for 6 MV photon beams.<sup>30-32</sup> Gardner et al measured the attenuation of the QFix kVue<sup>TM</sup> Calypso couch top using 6 FFF, and it was approximately 2.08%.<sup>14</sup> The result of this study showed that the attenuation of the couch top is 1.80% with a 6 MV photon beam, the little difference is caused by a different energy. The existence of the rails exacerbates the attenuation. From the off-axis dose curve, it can be seen that the attenuation can reach up to 5.46%-7.07% in the flat-portion of the rails, and can be 9.95%-13.09% in the edge-portion of the rails.

Considering the disturbance of the couch top to the dose distribution, it must be modeled in TPS. In this study, we measured the average HU of different parts of the QFix kVue<sup>TM</sup> Calypso couch top by its' CT image. The average HU of couch surface, couch interior, and supporting rails were -450, -930, and 250 HU, respectively. And this result was consistent with Gardner's. Comparing the calculated doses of the two models with the measurement, with “Rails Out,” the deviations between calculations of both models and the



**Figure 10.** The  $\gamma$  passing rates comparison of treatment plans between the revised model and default model at different angles.



measurement were small, all within the clinical tolerance. And the deviation of DCT was slightly larger than that of RCT. This may be caused by the little difference between the default couch model and the actual couch top, including the structure and the HU differences. With “Rails In,” it can be seen from the depth dose curve that the calculated depth doses of the two models were significantly lower than the measured curve in the built-up region, the two models clearly underestimated the scatter dose of the rails.

Although we scanned the couch top in the CT scanner, the difference between the dose of RCT and the measurement is still significant in the edge-portion of the rails. The structure of the rails was too complex, especially at the edge of the rails, it had a periodic lattice structure with 5 mm thickness. In this study, the slice thickness was 2.5 mm, the calculation grid was 2.5 mm, and the resolution maybe not enough to well consider the effect of the rails. Meanwhile, the AAA algorithm can underestimate the surface dose as reported.<sup>33</sup>

Some studies have investigated the dosimetric effects of the couch top for a variety of beam angles. McCormack et al found the beam attenuation of a carbon fiber couch insert on the Elekta SLi linac ranged from 2% (normal incidence) to a maximum of approximately 9% (incidence at angle of 70° from vertical).<sup>34</sup> This research showed the attenuation of QFix kVue™ Calypso couch top ranged from 2.41% to 8.79% with “Rails In,” and from 1.84% to 8.50% with “Rails Out.” The mean attenuation of the couch top and the couch rails is about 2.14% and 6.00%, respectively. The result is consistent with Gardner. Thus, it is better to avoid the angle range from 160° to 180° and 180° to 200° with “Rails In,” and 130-150°, 210-230° with “Rails Out.” In our department, the “Rails In” configuration was selected to maximize the available gantry clearance and minimize oblique beam transmission through the rails.

During the study, it was found that in the default couch top model, the edge-portion of the rails was a consistent structure rather than the periodic lattice structure. This was obviously wrong, and it seriously underestimated the attenuation at the edge of the rails, and the max deviation can reach up to 7.36%-13.41% at different depths. Meanwhile, at the upper flat-portion of the rails, the thickness in DCT is thinner than that in RCT, which also resulted in underestimating the attenuation, these explained the large difference between the dose of DCT and the measurement.

The  $\gamma$  analysis of the dose plane comparison also confirmed our previous discussion. When the rails were out, both models had a high passing rate, close to 100%; when the rails were in, the passing rates were all greater than 90% for RCT, which can meet the clinical requirements. The failed parts were mainly concentrated on the edge of the rails, which was consistent with the previous results of the off-axis dose. The passing rates of DCT were all lower than 72.7%, both failed in the flat-portion and the edge-portion of the rails. Hence, the default couch top model can't be used in clinical treatment and needs to be appropriately revised.

After the default HU of the edge-portion was changed from -1000 to -300, it was found that the calculated result became

better consistent with the measured result. The  $\gamma$  passing rate of the dose plane comparison was increased significantly, from 78.8%, 55.6%, and 48.7% to 89.2%, 92.4%, and 95.2% at the depth of 1 cm, 5 cm, and 10 cm, respectively. Plans with square field 20 × 20 cm at different angles were also measured to evaluate the accuracy of the revised model, and it also performed much better. To adapt more accurate parameter values for all energies, we will do further research and exploration. Furthermore, more verifications of treatment plans with the revised couch model should be done.

## Conclusions

This study has demonstrated that the calculated dose with the default model of QFix kVue™ Calypso couch top has a significant difference compared with the actual measurement, users should be cautious about using it in clinical practice before it is revised, it is better to avoid the beam angles that would pass through the rails. For the tumor in superficial positions, it is better to keep it away from the couch top to avoid the big calculation error.

The default couch model of QFix kVue™ Calypso couch top in TPS should be revised according to the actual measurement before clinical use. In our department, the “Rails In” configuration was selected to maximize the available gantry clearance and minimize oblique beam transmission through the rails. The value of edge-portion was set to -300HU and found a good  $\gamma$  pass rate at different gantry angles. Next, more verifications of clinical treatment plans with the revised couch model will be done.

## Authors' Note

Lingtong Hou and Huiqin Zhang contributed equally. Our study did not require an ethical board approval because it did not contain human or animal trials.

## Acknowledgments

Here and now, I would like to extend my sincere thanks to all those who have helped me make this thesis possible and better.


## Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

## ORCID iD

Shengyu Yao, MS  <https://orcid.org/0000-0001-5388-0636>

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