

Absorption measurements for a carbon fiber couch top and its modelling in a treatment planning system

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Introduction

Full carbon couch tops are widely used for radiotherapy treatments on linear accelerators. In contrast to their predecessors which were constructed with metal bars they have almost no limitations in choosing beam angles in treatment planning. In this work we have measured the absorption for the new Varian Exact IGRT couch top[®] for different setups. With the latest version of our treatment planning system (TPS), it is possible to model the couch top as a supporting structure with different options for parameter settings. We investigated the quality of the modelling of the couch top in the TPS and the influence on clinical dose distributions were analysed.

Material and Methods

The couch top, of which the surface consists of carbon fiber and which is filled with foam [1], was CT-scanned (120 kV) together with the phantom setup used for dose measurement. Within the TPS (Eclipse V 8.6) a model of the couch top was added as a structure to the CT slices and was included in the dose calculation. The 3 different predefined thicknesses of the couch top model, thin (50 mm), thick (75 mm) or medium (62.5 mm) were added and evaluated. For absorption measurement we irradiated a cylindrical, isocentrally placed PMMA phantom (diameter 20 cm, length 12 cm) varying gantry angle, photon energy (6, 15 MV), field size (4 cm, 10 cm) and position at the couch top (thin and thick part). Further we irradiated a 1 mm spaced moving gap dMLC field (6 MV) under different gantry angles. By defining HU values for the couch top surface and the inner material of the couch top the model has been fitted to the measurement. With the thickness and the mass density of the carbon fiber and the given relation between mass density, electron density and the resulting HU value from the CT, we could confirm the HU value of the carbon fiber in the model. We compared the farmer chamber measurement to the TPS dose calculation with the original scanned couch top and with the couch top model. In a 5 field IMRT prostate plan we investigated the influence of the couch top on the dose distribution.

region	length [mm]	overall height [mm]
thin end / head	400	50
transition zone	350	50 .. 75
thick end / feet	1250	75

Tab. 1: Size of the couch top

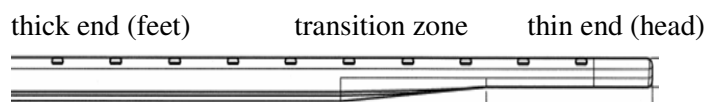


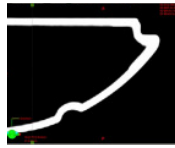
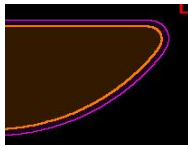
Fig. 1: Couch top design

components	mass density [g/cm ³]
cover/surface: carbon fiber	1.4 ± 0.2
inner material (foam): polymethacrylimide (Rohacell 51 [®])	0.06 ± 0.01

Tab. 2: Real couch top composition

region	carbon fiber thickness	
	top [mm]	bottom [mm]
thin end / head	0.85	1.05
transition zone	0.85	1.05
thick end / feet	1.25	1.25 .. 3.05
edge	2 .. 3.5	

Tab. 3: Carbon fiber thickness

localization	real couch top	Eclipse couch top model
surface/ carbon fiber	0.8 to 3.5 mm	constant thickness; 4 mm
height	depending on region	constant
height at transition zone	50 ..75 mm	62.5 mm
edge & grooves for positioning tools		
whole couch top	deflection	no deflection

Tab. 4: Comparison between real couch top and Eclipse couch top model design

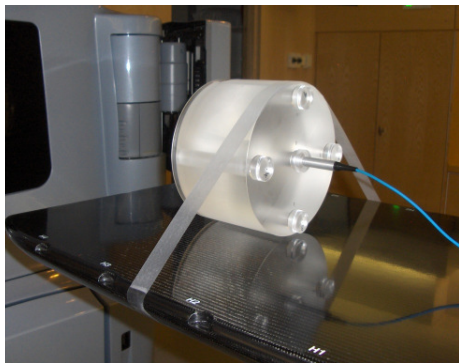


Fig. 2: Setup for the couch top absorption measurements: Isocentrically placed thimble chamber in a cylinder phantom (radius 10 cm).

Results

The outline of the Eclipse couch top model and the real couch top are nearly identical in transversal projection. The passage from the thin to the tick part is approximated with the medium thickness (62.5 mm). The thickness of the carbon fiber in the model is constant over the whole couch top in opposition to the real situation. Therefore the calculation of the HU value of the carbon fiber for the model yields in the feet end to a lower HU value than in the head end (Tab. 6, 7). But by taking HU = - 680 for the carbon surface and HU = - 950 for the foam of the couch top the agreement between measurement and calculations is within 1% both thick end and thin end of the couch top. The calculation with the real scanned couch top deviates from the measurement because of the rough spatial resolution of the dose algorithm in comparison to the small thickness of the carbon surface. For a 4x4 cm² the absorption is roughly 0.3% higher than for the 10x10 cm² field, for 6 MV the absorption is about 1% higher than for the 15 MV. For clinical situations, where the lateral couch position is variable (e.g. prostate), the deviation may be larger because the dorso-lateral fields are passing through the couch only partially.

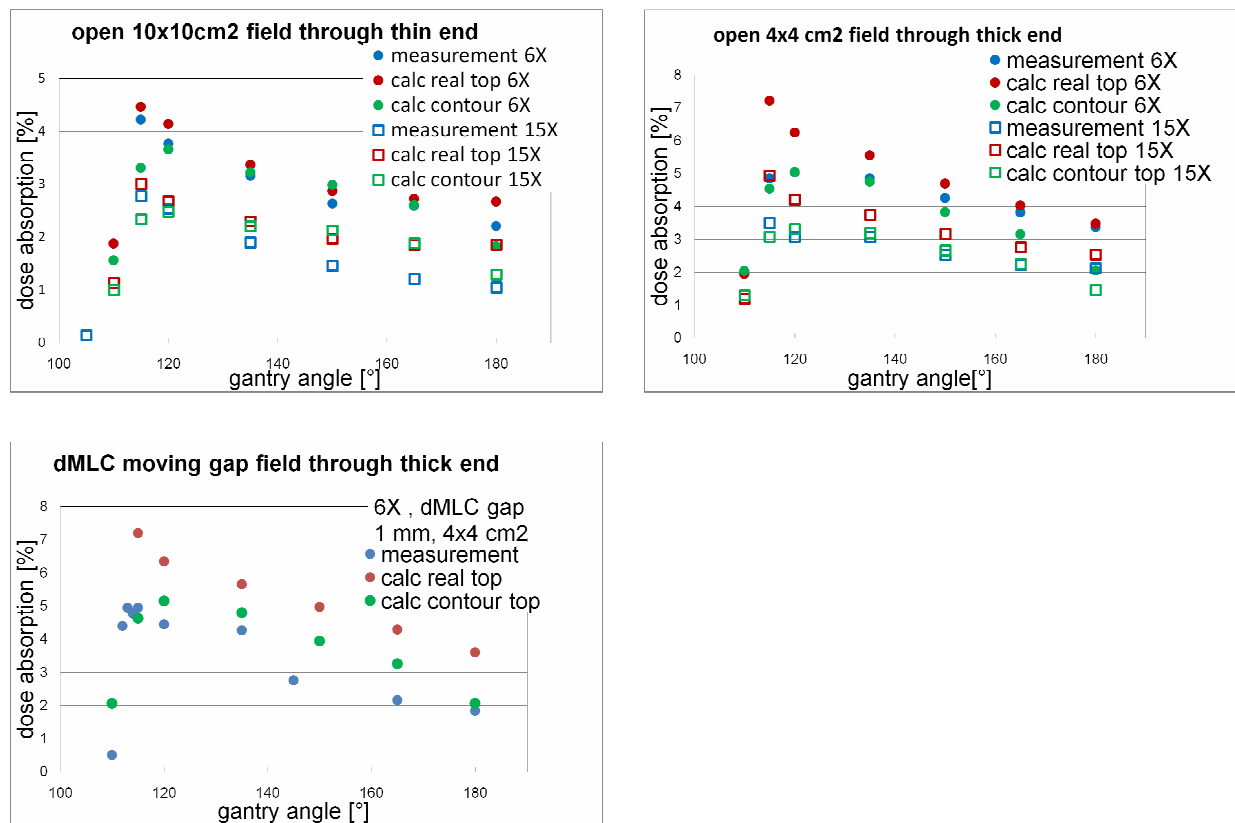


Fig. 3: Couch top absorption; comparison between measurement, top model contour and real scanned couch top

Absorption	thin part		thick part	
photon energy\gantry angle	180°	115°	180°	115°
6 MV	2.4%	3.5%	3.3%	4.5%
15 MV	1.2%	2.5%	2.2%	3.5%

Tab. 5: Couch top absorption by gantry angle 180° and 115° (nearly maximal value, worst case)

contour	HU (σ)	determination
internal	-950 (5)	measured in Eclipse
surface	-680	fitted to optimal agreement between measurement & planning (because of small surface thickness & rough spatial resolution)

Tab. 6: Determined HU values for the couch top

position	real surface thickness [mm] (top + bottom side)	model surface thickness [mm] (top + bottom side)	model surface density [g/cm^3] (real density*real thickness/model thickness)	calculated HU of the carbon fiber surface	water equivalent thickness [cm]
head end, transition zone	$0.85 + 1.05 = 1.9$	$4 + 4 = 8$	$1.4 * 1.9 / 8 = 0.32$	-710 ± 70	0.58 $0.58 \dots 0.72$
feet end	$1.25 + 1.25 = 2.5$	$4 + 4 = 8$	$1.4 * 2.5 / 8 = 0.43$	-620 ± 70	0.83

Tab. 7: Calculation of the HU for the carbon fiber (irradiation form gantry angle 180°); real surface density (carbon fiber) = $(1.4 \pm 0.2) \text{ g}/\text{cm}^3$; (assumption: constant relation between mass density and electron density and HU value for the carbon fiber)

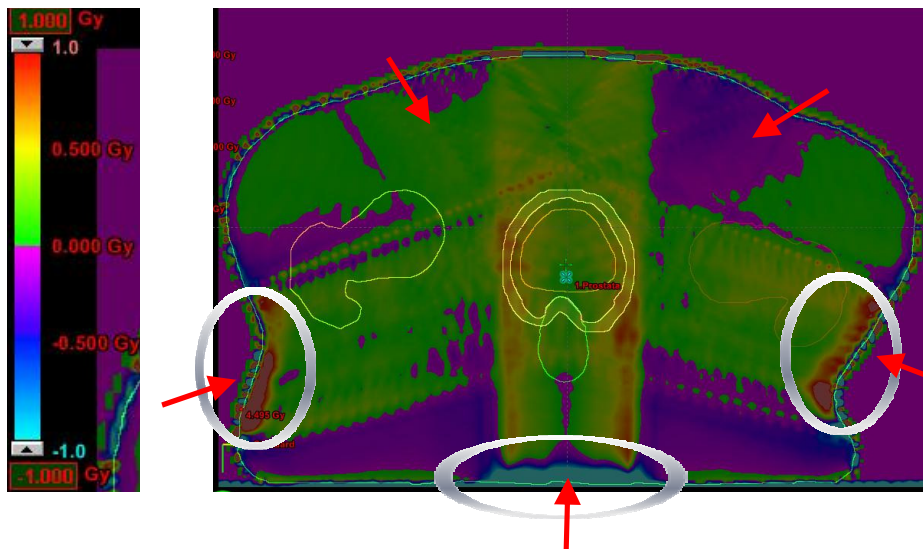


Fig. 4: Difference plan of two 5-field IMRT prostate plans with the same MU and fluence (Dose(PTV) = 70 Gy); difference plan = plan without couch – plan with couch (thick end); difference region: beam entrance of the field and near couch surface (build up)

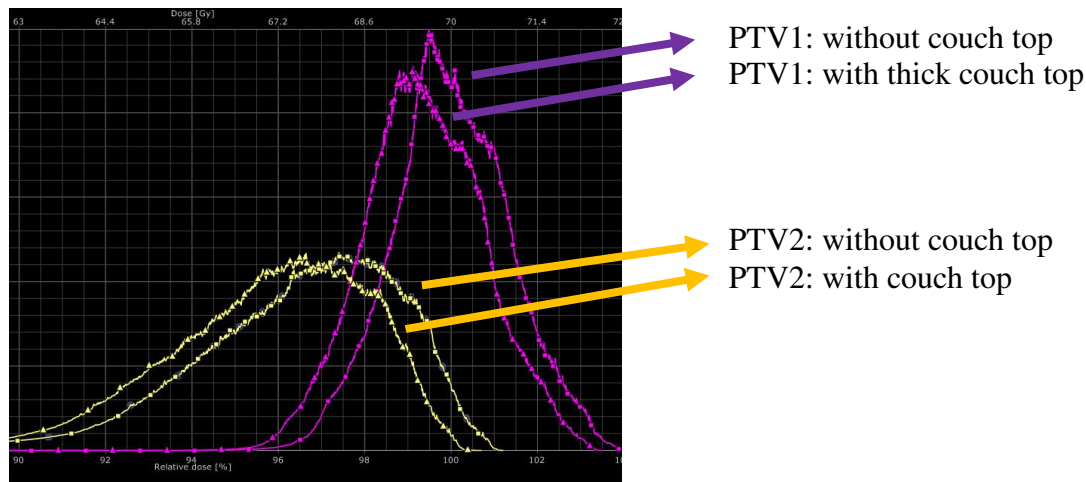


Fig. 5: Differential DVH for the high dose PTV (70 Gy) and the low dose PTV (54) for the two 5-field IMRT prostate plans (two plans with the same MU and fluence); triangle: plan including the thick end of the couch top; square: plan without couch; PTV1 (pink): 100% vs 99.4%; PTV2 (yellow): 96.4% vs 95.6%

Discussion

Advantages of the couch top are the stiff material consisting of only two components and the low absorption. The different thicknesses and the 35 cm long passage from the thin to the thick part of the couch top and the constant thickness of the surface in the model in opposition to the real carbon fiber surface may be disadvantages. An advantage of the Eclipse couch top model is the possibility to adapt the Hounsfield Units of the surface and the inner material. As in some clinical situations, the treated volume is located in the transition zone between thick and thin end (e.g. head and neck), the model is only an approximation. For a higher precision, exact modelling of the couch top and absolute indexing of the patient position on the couch top in lateral and longitudinal direction would be necessary.

References

- [1] Exact IGRT Couch, User and Maintenance Guide, Varian Medical Systems, P/N 100026454-14, Dec. 2008